THE DYNAMICS OF INDIGENOUS INNOVATION IN THE PORTUGUESE CAPITAL GOODS SECTOR

Fernando Carlos Cabrita Romero

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This work is based on a Ph.D. thesis of the author.

Contact details: fromero@dps.uminho.pt
fernando-romero@sapo.pt

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Abstract

In this research work the analysis of the process of indigenous technological change in the equipment goods sector in Portugal is made. The framework of analysis is based on evolutionary theories of technical change, on systems theory, on innovation systems theory, on theories of industrial innovation and on an ever-present historical perspective. There are two main thrusts behind this work. The first is the realisation that there are national differences in economic development rates and more particularly in innovation rates and that there is a need to explain those differences. The second thrust addresses the need to explain the variation at firm level and how the behaviour of firms is related to its innovative performance. A general model, based on the chain-linked model of innovation, is developed as a conceptual framework to achieve the goal of explaining variation at a firm level. The explanation of the reciprocal interactions between the two main conceptual blocks, the firms and the environment, is the final goal of this study. The main research questions are: What is the main determinant of Portuguese indigenous industrial innovation? Is it the political/economic/cultural institutional environment? Or is it the strategy followed by the economic agents? What is the relative importance of each factor in the process of indigenous industrial innovation?

Acknowledegment

My thanks to Luke Georghiou.

To Alexandra

PART I. GENERAL INTRODUCTION

CHAPTER 1. INTRODUCTION

By and large, the literature on the theory of technical change has focused its efforts and derived most conclusions from studies conducted in the developed and industrialised countries (DCs). The underlying rationale is that technological change is created in the developed countries and subsequently transferred to less developed countries (LDCs), by licensing or similar or other agreements. Most of the literature treats technical change in LDCs within the conceptual framework of technology transfer and neo-classical economic theories, assuming an almost completely passive and unproductive recipient in terms of knowledge and technology creation and generation.

This approach now seems to be insufficient from several perspectives. There is empirical evidence that indigenous technical change occurs in LDCs, although the nature, magnitude, rate and direction differ substantially from that in DCs. Prevailing theory fails, then, to conveniently explain the empirical evidence (Katz, 1987). Moreover, in as much as technical knowledge or, by and large, technical information, has some characteristics that make it a distinct factor of production, the technology transfer framework seems not to be completely appropriate to analyse technical change in LDCs. These characteristics include an endogenous nature and a tacit nature.

The endogenous nature of technical information prevents it from being treated as just another production factor on a notional production function. The technology transfer framework assumes an exogenous nature of technical change, whereby a given set of alternative technology packs is just waiting on the shelves of DCs to be chosen by LDCs and promptly assimilated and set on a production line.

The tacit nature of technical knowledge implies that a given package of technical information is not easily or even perfectly or completely understood, replicated or imitated. It rather emphasises the importance of learning and searching phenomena, in as much as they lead to peculiar, distinct approaches to technology or knowledge creation.

In this research work the analysis of the process of technological change within a less developed country - Portugal - is made from a different perspective. In search for a more useful approach, the framework of analysis is based on evolutionary theories of technical change (e.g., Dosi et al, 1988, Clark and Juma, 1987, Nelson, 1982, Metcalfe, 1993) and on an ever-present historical perspective. An evolutionary approach to the study of technical change will comprise two main conceptual blocks: the environment, encompassing and setting the general constraints and opportunities that the units of analysis must face, and the so called routines (using Nelson's terminology), the general behavioural procedures and action guidelines available to the units of analysis or entities, whereby the entities are considered the firms. The interplay between the two conceptual blocks will ultimately explain the output, i.e., the selection results.

In line with this approach, there are two main thrusts behind this work. The first is the realisation that there are national differences in development rates and more particularly in innovation rates and that there is a need to explain those differences. The second thrust addresses the need to explain the variation at firm level. The second one is a somewhat more ambitious goal insofar as it constructs a general model as a conceptual framework to achieve the goal of explaining variation at a firm level.

Consequently, the main general research question is to find out what are the determinants of Portuguese indigenous industrial innovation, or in a more detailed manner:

> What is the main determinant of Portuguese indigenous industrial innovation? Is it the political/economic/cultural institutional environment? Or is it the strategy followed by the economic agents?

There are complex interactions between each sphere of enquiry and each one bears an important impact upon the others. However, it is to disentangle those interactions and the assessment of their relative importance that is the main goal of this research.

The structure of the thesis is as follows: the first three chapters, which make up Part I, are of an introductory nature. The present chapter, which is a very short introduction, explains the motivation, the conceptual framework, the main research questions and the structure of the thesis. The second chapter describes the methodology and the reasons behind the choices that were made. The third chapter gives an overview of the industrial sector under study.

Part II includes chapters 5, 6, 7, and 8, and consists of an analysis of the features of the environment. The aim is to identify and highlight the factors that had more impact on the innovation trajectory of the industry as a whole.

The environment is seen as being made of several elements and related to macro-level institutional aggregates, where the concept of institution is used in its broader sense, potentially including, for instance, the price mechanism. The macro-elements of the environment are reduced to the following set:

- The national institutional set-up for knowledge creation and dissemination. This element includes universities and research institutes and, in a general sense, all the political or public bodies associated with the philosophy and management of this network.
- The national market element, including a set of variables usually used to describe its characteristics: demand and supply curves, structure, degree of protection, factor endowments, etc.
- The impact of the international institutional and market set-up.

The reason to focus on these elements, particularly the first two, since the latter is more ill defined and specified, is the conviction that peculiar characteristics of both elements varying from country to country have an important impact on the extent, nature and direction of localised technological change. More particularly, the analytical partition of the national institutional set-up (the environment/system) results in the following three sub-systems: the general economic environment, the education system and the research system, which are described and analysed in three separate chapters, chapters 5, 6, and 7 respectively. Chapter 4 is an introductory chapter to Part II including a review of the literature as well as the arguments that are behind the choice of this particular conceptual approach. Chapters 5, 6 and 7 portray each subsystem in a descriptive way but at the same time analyse their influence on individual technological capacities, and where appropriated and needed, the links connecting each sub-system and the overall impact on firm's behaviour. Chapter 8 summarises those perceived impacts and its relationships with the behaviour of the firms.

The environment itself determines to a certain degree the availability and choice of routines of a given set of units of analysis, but a random routine factor is also present. There is a whole range of procedures by which a firm can cope with a certain perceived signal from the outside exogenous environment. The following part of this work is an analysis of those possibilities and the way they impacted upon the life of the units of analysis (the firms). Within the general conceptual framework above described, and for the purposes of studying technical change in a specific environment, routines may be synonymous with strategy, defined in a broad sense, and more specifically synonymous with innovation strategy and R&D strategy. The set of factors that were considered relevant for the purposes of this study and for which information was sought are represented in Annex B.

Part III comprises the micro-component of this study, that is, it describes and analyses the results obtained from the field study. Chapter 9 is the introductory chapter to Part III, and it consists of a review of the literature as well as putting forward the arguments for the conceptual approach followed in this Part III. Chapter 10 is an aggregate analysis of the empirical results. Chapter 11 is an extensive and detailed description of the histories of each firm that was studied. Although rather descriptive it aims to conjugate practice and theory by advancing also detailed explanations for the trajectory of each firm. The chapter aims also to prepare the ground, in a thorough manner, for the next chapter, Chapter 12, which will generalise the individual analysis of the previous chapter and will propose a general model for explaining differential behaviour and innovation. Chapter 13 is a summary concluding Part III. Part IV, which includes the last Chapter 14, is a comprehensive conclusion of the thesis, whereby use is made of additional concepts to logically integrate all the conceptual and empirical topics covered by the preceding sections of the thesis.

CHAPTER 2. THE METHODOLOGY

2.1 Preliminary remarks

Ever since the research goals of this study were defined, the question was put of whether the methodology should be based on a broad mail survey, including a representative sample of all the industrial sectors, or if it should be based on a case study approach, including only one industrial sector. Because the study aimed at exploring a present situation determined by its past deeds, it was thought more appropriate to use the interview-based case study, due to the following reasons:

- knowledge of the exact variables that have affected most the innovative performance is partly unknown,
- an open-ended approach is more adequate to scrutinise the intricacies of the past,
- personal contact with the actors is more likely to bring about clues to as what has happened than a distant, impersonal questionnaire,
- possibility of collecting greater amounts of data from each unit of analysis.

The choice of a case study approach as opposed, for instance, to a mail survey brings an inevitable reduction in its generality, because the sample is, generally, much smaller. It would be probably best to follow a dual methodological approach. On the one hand, a mail survey would be conducted, encompassing a representative sample of the population, while on the other hand, a smaller sample would be chosen to conduct case studies. This would combine the best of two worlds, that is, the depth provided by the case studies and the width made possible by a mail survey, in spite of the fact that a mail survey would probably capture a fairly static picture of the scene. But, due to pragmatic limitations related to time availability and finance capacity, it was decided to proceed only with the case studies approach. This could provide a fairly good amount of study material and it could fulfil appropriately the research goals provided that the main difficulty, which lay in the capacity to design a questionnaire that would capture the dynamic interactions between the firm and the environment and within the firm, could be surmounted.

2.2 The choice of the sector

The reason for choosing the capital goods sector is that we assume that this sector has a crucial role to play in terms of the innovative performance of the whole of manufacturing industry, acting as a fundamental point of diffusion of technological capabilities throughout the society, and more particularly in terms of its indigenous capacity to innovate (Rosenberg, 1976). Thus, studying what happens or happened within this sector may eventually bring about more understanding to the innovative performance of Portuguese industry, than say, looking at another sector whose perceived technological characteristics may rend it less useful to that purpose. Thus, while the study concentrates on just one sector, it is hoped its conclusions can be extrapolated to other sectors as well.

Indirectly there is another practical advantage in choosing this sector, and that is the relatively low number of firms operating in this sector and consequently the representativeness that a small sample will have. According to 1993 statistics there were approximately 2795 firms in business producing equipment for the agriculture, metal-working, food and beverage, textiles and shoes and building sectors and also weighing, refrigeration, industrial ovens, optical and scientific equipment (Associação dos Industriais Metalúrgicos, Metalomecânicos e Afins de Portugal- Associação Nacional das Empresas Metalúrgicas e Metalomecânicas, 1997). In another study (Vasconcelos, 1994), a finer analysis of the equipment goods sector points to an even smaller number (342 firms) which seem to represent 90% of total sales of the sub-sector. If so, the representativeness of the sample acquires another significance.

2.3 Defining the sample

Regarding the case studies, the sample size was inevitably reduced to a small number of firms, given resource and time limitations. Its size, however, was such as to allow for a certain degree of heterogeneity or else it would be of little analytical use. The intention was to have a group of innovative firms confronted with a group of non-innovative firms and make a comparative analysis of these firms based on the dynamics of their history.

The sample consisted of nineteen firms. It was based on a comparative methodology between two groups of firms matched by a set of criteria (inspired by the SAPPHO matched pair methodology). It consisted of two groups: the “innovative group” and the “non-innovative group” or "average group". We think this procedure is equivalent to the experimental group and the control group methodology adopted in the social sciences. In this case, the experimental group consisted of the “innovative” group and the control group was the “average” group. The objective, as stated, was to see if common behavioural patterns within the groups and different behavioural patterns between the groups could be discerned that in turn could point out regularities.

2.4 Preliminary comments on the process of building up the sample

Each firm was individually matched with a pair in the other group. The criteria for matching the firms were the similarity of the product lines and the size of the firm, as measured by the total number of employees (this criteria was not strictly followed; see below). It is in this procedure that we can find similarities between the SAPHO methodology because, like the SAPHO study, it is the product (or innovation in the case of SAPHO) that is matched, and not necessarily firms. The firms are matched because the products happen to be manufactured in a certain firm. In the SAPHO case the innovations were divided into the successful ones and the unsuccessful ones. In this study the products are divided into the innovative ones and the average ones. Those are the links with the SAPHO methodology. Otherwise, the methodology closely resembles that of the experimental-control methodology, whereby we compare two groups and not necessarily individual elements of the groups. However, the groups are build-up in such a way that the whole of their elements confers the group definite characteristics. The experimental group is the group with the relatively more innovative firms. Its salient and defining characteristic is its innovativeness. The control group pretends to include the relatively less innovative but not exclusively so. It can also include innovative firms. This is possible because of the individuality of the pairing of the products and firms. Firms (products) are only compared with its pair, not with the other firms (products) in the experimental group. As such, it is possible that one firm in the control group is relatively more innovative that another firm, other than its pair, in the experimental group. By virtue of these factual possibilities we can have the presumption that the control group is representative of an “average” condition of innovative performance of Portuguese firms, which, then, is its defining characteristic as a whole.

Asides from the mentioned, another advantage of pairing each firm in this way is that we can create a condition of analytical bipolarization that will force the surfacing of extreme characteristics. By imposing extreme conditions, the probabilities of finding factors that are illustrative, illuminating and explicative increase substantially. On the other hand, we can incur in the danger of extrapolating uncritically the artificial analytical conditions to construct conceptual frameworks that are used in the explanation of real conditions and as such distort the perception of reality.

A disadvantage of the matched pair methodology is the subjectivity inherent in the definition of “similar products” and “innovative” and “average” products. Here, similarity of products means that the products perform similar functions, using (at least some) similar technological and technical principles and constructs. The subjectivity in defining innovative and average products is even greater. Below we will describe how those problems were tackled.

2.5 Building up the sample: the details

The innovative group was the first group to be selected. The rationale for selecting the innovative group case studies was essentially based on the characteristics of the products manufactured by the firms, which included the following: new features, quality and performance and new products (sector-wide or world-wide). These criteria of innovativeness were confronted with the following sources of information and the subsequent organisation of that information determined the selection of the innovative group. The sources of information for selecting the innovative group were: reports in newspapers or industry journals (referring names of firms known by their above average innovative capacity), award winning enterprises, opinion of the professional association of the sector (who provided a list of firms that, according to their opinion and the criteria of innovativeness referred above, were above average performers), opinion of individuals (industrialists) knowledgeable of the sector (a dozen individuals provided each one a list of firms who they fought performed better than average in terms of innovative output) and information on expenses in R&D or human resources devoted to R&D by individual firms as provided by national statistics.

It turned out that there were quite a few firms that were common to two or more sources of information, so that the first selection of the innovative group was based on the intersection of the information from all the sources. After that, if there were two or more firms in the same product line, one of them (or two, in one of the product lines) was arbitrarily chosen and the others rejected. To assure that a broad range of size classes was included (the smallest firm had sixteen employees and the largest twenty five hundred) the last step was repeated, first replacing the previously rejected firms and then choosing again another firm whose size was more adequate to our goal of including a broad range of size classes. This was the way the ten firms that composed the innovative or experimental group were selected.

Each firm of the "non-innovative" group sample was then selected by randomly picking up a name out of a list of firms that were included in the same product line and confronting it with its pair. The professional association of the sector (Associação dos Industriais Metalúrgicos e Metalomecânicos do Norte / Associação dos Industriais Metalúrgicos e Metalomecânicos do Sul, 1994) provided this list, which was quite a long one. The procedure was, in detail, as follows. The firms in the list were previously grouped according to their product line (according to a standard classification developed by the Association). We then picked up a firm from the previously selected innovative group and identified its product line. We then went to the list, looked at the group that contained that product line and randomly selected one firm with approximately the same size, i.e., within an error of more or less than 10% (this was not always possible). Confirmation was then sought that the firm was really in a product line similar to its innovative pair (e.g., by telephoning the firm). If it proved not to be the case, the last step was repeated. We repeated this procedure for each and every one of the ten firms of the innovative group and chose from the list the respective pair. This was the way the matching exercise was done and this was the way the average or control group was selected (see below for some limitations in this process).

The sample of firms selected for this study is presented in Annex A, indicating the main product lines, previously manufactured as well as presently manufactured, in order of decreasing importance (in terms of percentage of total sales).

2.6 Concluding remarks on the process of building up the sample

Ideally, the intention was that matched firms would be in the same size class and competing with each other, but this was found to be a more difficult task than anticipated, due to the small size of the industrial structure and due to the niche strategies pursued by most of the firms. Consequently there were difficulties in finding firms operating in the same product line. For two of the firms it was not possible to find a perfect match by type of product, although there were other firms operating in the same product line. The reason underlying this is that the allocation of each firm to each group is based on its relative performance to its pair, and those firms were performing at similar levels (according to our criteria of product improvement, quality or newness). In those cases, a firm operating in a product line whose technology had close affinities with the technology of the product manufactured by the firm in the "innovative group" was chosen.

In another instance, namely that regarding the largest firm, whose main product line was in electricity power stations, the firm was left as a stand-alone case because it was not possible to find another firm operating in the same product line. The only alternative was a subsidiary of a multinational firm, but its activities on Portuguese soil were mainly as a commercial and manufacturing outpost so that conclusions based on behavioural comparison related to innovative performance between the two firms were bound to be fallacious, if they were only to be made based on the activities of the firms in Portuguese territory. It was decided not to discard this case because otherwise the sample would not be representative of the whole population regarding the size dimension.

2.7 Preparing the field study

The empirical information was obtained by visual observation of the premises of the firms and during personal interviews with the owner/manager of the firm or with a Director, following an interview guide that contained a set of topics and a semi-structured questionnaire. The list of topics and the questionnaire is in Annex B. It includes all fundamental quantitative aspects and qualitative topics covered in the interviews. The questionnaire, in conjunction with the list of interview topics, served the dual function of being simultaneously an aide-mémoire and a framework for conducting the interview as well as a rather precise structure for the quantitative part of the interview.

The topics to cover during the interview were first subject to an initial structuring exercise whereby an initial draft of the questionnaire/aide-mémoire was made. The ideas behind the topics and the questionnaire were itself influenced by a series of previous contacts with a number of industrialists where there were informal discussions with the aim of making an exploratory investigation regarding the discussion of research goals and the adequacy of the intended research methods.

It was then followed by a pre-pilot phase. The pre-pilot phase consisted of a series of interviews aiming at improving the draft of the quantitative part of the questionnaire, to determine whether the topics to be addressed in the interviews were adequate to the characteristics of the target population and adequate to the purposes of the study and to see if any relevant topic was missing. The interviewees were informed of the research goals and invited to discuss it and to suggest improvements, either in general term or specifically to the structure of the aide-mémoire. The pre-pilot phase consisted of interviews with four individuals, namely, two industrialists, the director of an interface institution and a university professor. One of the industrialists was a mechanical engineer, who worked first in product development in a small firm, and later in a division of a large firm, first as an engineer in the product development department and then in the commercial department. The second one was also a mechanical engineer who worked in a firm recently bought by a multinational firm. He had several contacts with the university, related to development of products and also as a teacher. The director of the interface institution had previous industrial and university experience.

After incorporating into the aide-mémoire and interview topics some conclusions reached during the pre-pilot phase, the aide-mémoire was tested twice in a real live situation. The objectives of the pilot phase were the same as those of the pre-pilot phase with the addition of aiming at testing and assessing the whole exercise with concrete experiences and, specifically, testing and measuring the amount of information and quantitative data that could realistically be retrieved under time constraints imposed by real conditions. The pilot phase consisted of two interviews with two industrialists, both with high level executive functions inside their respective organisations. The interviews were conducted so as to emulate as far as possible real conditions. Contrary to the interviewees in the pre-pilot phase, the interviewees in the pilot phase were not told that they were being used to test an interview script.

2.8 Specifying the information to be collected during the field study

The final outcome of all the above mentioned preparatory steps was systematised in the document that is present in Annex B. The document is composed of two parts: one of the parts contains all the interview topics, their precise definition, the objectives behind them and the relation with the questions of the aide-mémoire. The other part is the questionnaire properly speaking which, although it was elaborated to capture the quantitative part of the information, it also contained the interview topics and as such served also as an aide-mémoire.

The topics of the interview were constructed having in mind two things: first, an historical perspective was absolutely necessary. This was so because it was necessary to abide to the conceptual framework outlined previously, which presupposed an evolutionary and dynamic perspective of the process of indigenous innovation. Furthermore, in order to achieve the research goals we had committed ourselves to pursue it was essential an historical perspective. Second, the more information we could collect, the better, because we had very few clues as to what factors could be more important. As a consequence, as many topics as possible were in the aide-mémoire because we did not had a precise indication of what variables or factors would be more important, i.e., we wanted to minimise the risk of not including the request for information that could prove to be precious later on. Many of the factors we included were known and inspired on the literature (OECD, 1997), such as the sources of innovation, barriers, demand conditions, etc. Others were influenced by knowledge of the specific Portuguese conditions and the perception that they were important factors in explaining the indigenous innovative pattern and its evolution (such as the qualifications profile, the type of production equipment and how old it was, financing conditions, organisation and decision making, etc). Others still were introduced because they fit logically within a certain topic.

As it was mentioned before, one of the great preoccupations was with the historical perspective of the firm. One of the first topics (the third one) implied that the interviewee gave an historical perspective of the firm. It was a preliminary introduction to the more detailed aspects that would latter be asked for. It acted as a “situating” exercise and a way to have a comprehensive perspective of the firm. If possible, the history of the firm was divided into defined periods, subjectively dictated by the interviewee. They could provide important clues to periods of discontinuity in the firm.

Table 1. List of topics used in the fieldwork.

1. Date of start-up
2. Ownership status
3. A historical perspective of the firm
4. Initial product line/range and its subsequent evolution until this day
5. Factors deemed to have a direct relation to innovative performance:
    a) Technical knowledge
    b) Demand for the product(s)
    c) Source of technology and its impact
    d) Customers
6. Type of production equipment
7. Finance
8. Organisation and management
    a) Functional layout.
    b) Decision-making.
    c) Managerial techniques.
    d) Marketing.
    e) Internationalisation.
9. External conditions
    a) Government influences
    b) General institutional environment and its impacts
10. A historical account of the most important innovation (or the most significant failure) and how it came about.

After this introduction the interviewee was asked about the details, always in a historical perspective. Details were asked about the evolution of the following aspects: the product lines, production methods and equipment, number and qualification of personnel, demand conditions faced by the firm, financing conditions, organisational and management methods and techniques, among others (the details are in the aide-mémoire, Annex B). The conversation was not rigidly oriented, quite the contrary. In general, mention was made of the main topics and it was left to the interviewee the task of explaining the situation of the firm. It was expected that during his intervention crucial aspects related to the firm would come out amidst the other standard information that was being requested systematically but not forcefully. The same methodology was applied when the interviewee was asked about the way he perceived external or environmental features (such as government influences, social conditions, supply conditions, etc.). Annex B states in precise terms the objectives that are behind each topic and each question. Once again we should say that quite a few were (originally) exploratory, since there was no prior knowledge of what the importance of a particular topic would be.

Table 1 contains a list of the topics. Only the topic title is present. The reader is referred to Annex B for a complete specification of the objectives and contents of the topic as well as its relation to the questionnaire/aide-mémoire.

2.9 Some aspects related to the analysis of the data and the identification of the relevant variables.

After interviewing all the nineteen firms and collecting all the possible information, according to the topics specified in the aide-mémoire, the analysis of the data was made, a task that lasted several months. The method for identifying and selecting the relevant variables, namely those that are present in Table 48, is now described.

First, all the questions on the aide-mémoire (in Annex B) that could possibly be codified were codified in terms of continuous, nominal or ordinal categories. Some of the questions were already quantified, and as such, the task of coding was made easier or indeed automatic. For instance, the variable “graduate intensity” defined as the ratio number of graduates in the firm/total personnel of the firm was quite a straightforward task implying only the calculation of the ratio. Another straightforward example is the variable “use of CAD” which was coded as a nominal variable with only two possible outcomes, zero or one: if the firm used CAD the variable would take the value one, if the firm did not use CAD, the variable would take the value zero.

Other variables implied the analysis of the information collected during the fieldwork and its classification into categories. For example, the variable “predominance of production machinery”, coded also as a nominal variable, implied the creation of two categories: one of the categories was defined as a firm whose number of manual production machines exceeded 50% of the total number of production machines, the other was defined as a firm whose number of manual production machines was less than 50% of the total number of production machines. The threshold of 50% is quite arbitrary. It was possible to establish another percentage (and, in fact, during the analysis, several similar variables were created differing only on the threshold value; however, the statistical significance was not affected by the change in the threshold values). There are other instances of this kind of exercise implying thorough analysis of the disparate outcomes of the empirical results followed by a systematisation of those results into arbitrarily defined exhaustive categories. One example is the variable “type of strategy”, coded as a nominal variable, which included the following categories and respective values: if the firm had the routine procedure of elaborating formal medium and long term planning exercises the variable would take the value 3, if the firm had only the routine procedure of elaborating medium-term formal planning exercises the variable would take the value 2, if the firm did not have any routine procedure of elaborating formal plans but nevertheless had definite non-written ideas of what goals it should achieve and when and how to achieve them, the variable would take the value 1, and if the firm did not have any formal or informal routine planning procedure and its action was oriented only by the demands of daily compromises, the variable would take the value 0. These four categories exhaust all the possibilities revealed by the analysis of the empirical results. If there were other firms in the sample that did not fit into any of these categories it would be necessary to create another category. But according to our perception, that was not necessary. Another example of this kind of coding procedure was done with the variable “type of domestic customer”, “type of training”, and others.

Another group of variables was codified from the start into ordinal categories. They were originally formulated as such and they were included in the questionnaire as questions that demanded the active involvement and the judgement of the interviewee. The same scale was used for all these variables, namely a five-point Likhert-type scale: 1 for insignificant, 2 for slightly significant, 3 for moderately significant, 4 for very significant and 5 for crucial. In all cases the interviewee did the scoring. There were quite a number of variables that took this form (cf. Annex B). Important examples (i.e., variables that are in Table 48) are, for instance, the variables “importance of external competition” or “competition based on quality and performance”.

It was not possible to codify all the empirical information. For instance, traits such as “adaptive capacity”, “flexibility”, “vision of the future”, among others, were perceived as important characteristics of the firms but were nevertheless impossible to codify. The variable "Approach to product conception" represents an example of a trait that was possible to codify. The codifying exercise produced, in the end, one hundred and thirty five variables (including continuous variables, nominal variables and ordinal variables).

The task now was to see which variables were useful for our purposes. To do that we introduced all the variables in a statistical software package and performed statistical tests, namely regression statistics and non-parametric tests. These were the statistical tests whose outcomes determined the selection of the variables that are present in Table 48. These variables are all explanatory variables. There was only one dependent variable, namely the “innovativeness” variable. This variable is a nominal variable that can take two values: zero or one. If the firm belongs to the “innovative” group the variable takes the value one, if the firm belongs to the “average” group the variable takes the value zero. After exhaustive tests, the twenty-two variables that figure in Table 48, in Chapter 10, came out as the ones that showed up statistically significant test results and they were retained. All the other remaining one hundred and thirty variables were discarded. A note on this procedure is on order. Apparently we proceeded in a not very orthodox way, since we are applying statistical tests that presuppose randomness to a sample whose random nature is not established. We believe that the procedure described in section 2.5 and section 2.6 is fairly close to a stratified random sampling. However, there are doubts about that. The way that the innovative group was chosen was not strictly random (it was a deliberate grouping of recurrent firms) and the matching pair exercise and the need to incorporate the size dimension did not follow strictly the rules for random sampling. However, we thought that there was no other way to make the analysis and the selection of the variables in due time because of the wealth of information we had. On the other hand, the selection could have been done through visual methods or through descriptive statistics, but such a cumbersome procedure was, at the least, unjustified, if all the statistical tools specifically created to address and facilitate tasks like those we embarked on, were ready available. Nevertheless, a final comparison between the results of non-parametric and regression tests and the descriptive statistics was made and, as expected, they were perfectly compatible. Due to these shortcomings only the descriptive statistics are present in this study (in Annex C).

CHAPTER 3. AN OVERVIEW OF THE EQUIPMENT GOODS SECTOR IN PORTUGAL

In this brief description of the industrial sector we shall speak not only of the equipment goods sub-sector but rather of the whole metallurgical sector, embracing the manufacture of metallic products as well as the upstream basic steel sub-sector. We shall do so because all the sub-sectors are somewhat connected in terms of skills and technology in spite of the sector's great heterogeneity. We shall however refer specifically to the situation of the capital goods producer whenever appropriate and possible.

The metal sector has been a relatively important one in the industrial structure of Portugal for quite some time. It has been, and it certainly is today, a sector with mixed characteristics. One the one hand, its socio-economic relevance comes from its quantitative importance in terms of employment and number of establishments. On the other hand it leaves much to be desired in terms of its qualitative features. It has long been like this and recent qualitative developments were not enough to radically alter the relative state of things. It somehow reflects the intermediate position of development that characterises Portugal. Quantitatively its industrial structure reflects a considerable activity and production diversity in the metal sector but in terms of scope, or technological capability, the horizons are more restricted.

Macedo (1982) refers to the stimuli given to industrial activities during the second half of the 18^{th} century and to the innumerable metallurgic workshops that were set-up during that time but he also stresses that the industrial development that occurred at that time was characterised by an "extensive" nature, i.e., by an enlargement of existing activities and production and not by a significant improvement or upgrading of the existing techniques of production. Most of the establishments were small regional workshops based on handicraft methods of production and satisfying local needs. The more important factories were state-owned facilities producing military equipment located in the capital city.

Overall the situation did not change much during the 19^{th} century. The sector remained structurally important in quantitative terms but qualitatively it did not make any kind of dramatic leapfrogging although it continued a steady and regular improvement path. By this time there were three main geographical centres of concentration of the industry. One was in Lisbon, which was the most important one, both in quantitative as well as qualitative (technological) terms, another was Porto and a third one was Guimarães. This last industrial concentration was quite specialised, namely in cutlery, and its presence dates back from historical times (Pereira, 1917).

The 19th century, particularly the 2nd half, was characterised by a gradual industrialisation process of the country and the substitution of the small local workshop or the domestic worker by centralised production in factories. The myriad of small workshops were confronted with the improved quality and the low prices of (mostly consumer) products manufactured by the larger facilities that existed in the main urban centres (Lisbon and Porto) that were technologically more sophisticated and enjoyed economies of scale. A considerable proportion of these facilities were foreign owned or else foreign capital had an important stake in it. According to numbers advanced by Monica (1982) based on Serrão (1978) and industrial statistics of 1890 there were, in the 1880s, approximately 2800 people employed in Lisbon, 1200 in Porto, 1000 in Guimarães and about 200 scattered around the rest of the country, reflecting a considerable downsizing of the sector (Macedo refers the existence of 572 blacksmiths in 1796 only in one remote province). The main production is still consumer goods and not investment goods (i.e. machinery). But there is national production of machines, inclusive of steam engines. However, the majority of them are imported. In 1917, only about 10% of the machines in operation in the industrial sector were made domestically (Mónica, 1982).

Overall the sector went through a process of concentration and technological upgrading (the Bessemer process is introduced in 1905) in the three districts mentioned, and it was characterised by a considerable heterogeneity and perhaps duality. On one side there are factories with a reasonable dimension (but none of them very large) and using state of the art machinery. Some of these factories are foreign-owned, other are the state-owned factories and others still are owned by nationals. Most of them, if not all, employ foreign technicians. Production is not specialised. The product portfolio is diversified, reflecting the limitations of a small market. Eventually the most important products are metallic products and structures. On the other side there is a vast majority of small factories or small workshops producing a vast array of consumer products or small metallic structures.

From 1880 to 1930 the employment in the sector increases three-fold and the imports of iron increase two-fold but the consumption per head in 1930 is still at a very modest 17.5 kg (compared with 130 kg in France). Development remains gradual. The intentions to promote the sector, via government initiatives, especially by creating a national basic iron foundry and steel industry and by supporting domestic producers, is never really put into practice at this time (i.e. until the end of the 2nd World War). Almost all the raw material is imported, and there are no conditions for treating the national production of mineral iron (which was anyway diminutive).

The situation will change after the 2nd World War when finally the industrial take-off took place. The lack or difficulty of foreign supply of components and machinery during the war period stimulated the domestic production of components and machines, whenever there were necessary conditions and know-how. It also alerted the country to its excessive dependency on foreign sources. Thus, it is under this stimulus to increase auto sufficiency that government supports the creation of a national basic iron and steel industry (Ribeiro et al., 1987). There are also attempts to support and protect both the heavy and light mechanical industries. The heavy mechanical industry benefits from the general expansion of national infrastructures (electrification, railways and ports). The plans to support and protect the lighter industries are not so successful. Plans to initiate national production of cars are once again doomed to fail. They were not the first ones (Rodrigues, 1995) although these efforts were preceded by the largest evaluation procedure to date. However, by this time (1950s), producers of motorcycles were already in place. The objective of the implementation of a car production facility was also to develop the supporting supplier industries. The failure of the plan limited the development of capital goods producers. But this development was also limited by other factors such as: the small dimension of the Portuguese market (the demand for capital goods was less than proportionately adequate to the size of the population), lack of indigenous capacity in certain technological fields, competition from abroad and consequent reluctance of the national supplier dominated industries (such as textiles) to buy domestic products (generally of inferior quality) and also lack of a coherent and constant government policy related to procurement and fiscal incentives to stimulate the acquisition of domestic capital goods.

In any case the following decades (the 1950s, the 1960s and early 1970s) saw the equipment sub-sector grow at an enviable rate of 11.3% (Table 2).

Table 2. Average annual growth rates for the metallurgic sector, 1958-1990.

Sub-sector	1958-1973	1973-1990
Basic Metallurgy	11,7%	6,4%
Non-metallic Minerals	8,8%	5,5%
Metallic and Electric Equipment	11,3%	-0,8%
Transportation Equipment	-	0,4%

Source: Neves (1994).

It was indeed a period of above average growth for Portugal when it experienced the real industrial take-off. The share of the sector in total industrial output grew from 16.2% in 1958 to 22.8% in 1990 (Neves, 1990) and 20.7% in 1993 (INE, 1997a), but it is still well under the share of the sector in other developed countries which is about 40% (this numbers are for basic metallurgy, metal products, non-electrical machinery, electrical machinery, transport equipment and professional goods). Within the European Union area only Greece shows similar numbers, namely 23.0% in 1990 (OECD, 1992b). So, in comparative terms, the sector does seem to show a certain underdevelopment in spite of its considerable growth during the last decades.

The heavy mechanical sector particularly benefited during this period, eventually more than the light mechanical industries, due to the influence of considerable infrastructure development. So, in a certain sense, the previous industrial structure and product portfolio was maintained, characterised by a few large firms, now more specialised, technologically more advanced and particularly active in metallic structures or products, and a large population of small firms, many of them technologically laggard. However the product portfolio improved considerably. Almost everything was now produced nationally as a result of a policy of import substitution, although many producers were subsidiaries of multinational firms. There was also a greater preoccupation with the impacts of large firms' sub-contracting activities on the production of domestic firms and there was more preoccupation in incorporating national components in final products. However, indigenous technological capabilities are still modest. In an analysis of a group of heavy mechanical firms, Gomes et al. (1975) refer to the systematic recourse to external engineering, which probably reflects domestic deficiencies, and which also has the perverse effect of diverting to foreign producers possibilities for national producers of equipment goods. The author also stresses the relatively low figures of investment in design and project and the accompanying impacts in terms of building up internal technological capability (and the perhaps excessive reliance on external know-how through licence agreements or other agreements). The position of suppliers of components and other light equipment to the producers of heavy equipment seemed nevertheless to be ameliorating relative to the past.

By the early 1970s the portfolio of engineering products was already relatively sophisticated, including some products of considerable technical difficulty. Table 3 represents a sample of those products and the technological complexity associated with them.

Table 3. Engineering products in Portugal by the mid 1980s.

Commodity	Complexity index	Start of production	Commodity	Complexity index	Start of production
Extracting presses	125	X	Other metal-cutting machine-tool	72	X
Sea-going bulk carriers	190	X	Planning, shaping machine-tool	79	H
Reaming machines	86	O	Locomotives, electric	276	X
Garden tractors	109	X	Excavating ,machine	68	X
Other metal-forming machine tool	85	X	Milling machines	74	V
Electric furnaces	79	X	Wood-working machine-tools	75	V
Fuses, electrical	47	V	Locomotives, diesel	272	X
Switches, electrical	47	V	Combine harvester and threshers	100	V
Rail motor passenger vehicles	208	H	Metal-working presses	94	H
Threshing machines	52	X	Lathes	95	H
Forging and stamping machines	90	V	Looms	166	H
Transistors, crystal diodes	83	H	Typewriters	139	O
Scales, industrial	116	H	Sound, tape recorders	70	V
Passenger cars, assembled	167	H	Diesel engines, excl. car	129	X
Road tractors, assembled	157	H	Cables	36	H
Graders and levellers	85	X	Internal combustion engines	96	H
Grinding and sharpening machines	63	X	Transformers, >5kV	124	H
Transformers, <5kV	38	H	Electric motors, >1HP	115	H
Fertilisers distributors	56	X	Ploughs	43	X
Drilling and boring machines	83	H	Tankers, launched	266	H
Motorcycles	92	H	Other sea-going merchant vessels	213	H

Source: UNIDO (1988).

Note: The UNIDO (Technological) Complexity Index does not pertain to the product itself but to the technological requirements for its production.

Legend: H = production started before 1971; X = production started in 1971-1975; V = production started in 1976-1980; O = production started in 1980-1984.

The presence of a Porter-like demand structure was also improved when a number of multinational car producers established manufacturing (and not only assembling) factories in Portugal during the 1980s. As a result of that certain sub-sectors of the light mechanical industries have improved, particularly in qualitative terms. It had a relatively important impact in terms of producers of components, and also of producers of equipment goods.

In spite of these developments the sub-sector of producers of equipment goods in Portugal was small by the mid 1980s. Rendeiro (1985) says that in 1985 there are only 20 firms manufacturing machine-tools whereby ten of them represent 90% of national output (of machine-tools). Perhaps the number of firms advanced by this author is excessively diminutive, because only machine-tools for metal work are considered. In spite of the small number of firms, their average dimension is not less than the average dimension of comparable European firms (i.e. basically medium-small firms). Aggregate statistics seem to support Rendeiro regarding the smallness of the sector. Domestic production covered only 17% of total consumption of non-electrical machinery in 1986 and in 1992 the number was at 14% (Table 4).

Table 4. Ratio exports/imports in the metallurgic sector.

	1986	1992
Metallic products	1.06	0.79
Non-electrical machinery	0.17	0.14
Electrical and other machinery	0.57	0.58
Transport equipment	0.55	0.36

Source: INE (1997). *Contas Nacionais, 1986-1992.* Instituto Nacional de Estatística. Lisboa

Technologically there is great diversity with some firms achieving technological proficiency by a mix of technology transfer through formal agreements and/or imitation or creative imitation followed by a gradual incorporation and development of technology specific and indigenous to the firm.

Table 5. Annual growth rates of the metallurgic sector (1958-1990).

	Machinery		Basic metallurgy		Transport equipment	
	Million Esc. (1990 p.)	a.a.g.r.	Million Esc. (1990 p.)	a.a.g.r.	Million Esc. (1990 p.)	a.a.g.r.
1958	62474		6583			
1959	68571	9,8%	7500	13,9%		
1960	80915	18,0%	6259	-16,5%		
1961	88251	9,1%	9514	52,0%		
1962	93209	5,6%	15593	63,9%		
1963	99389	6,6%	16762	7,5%		
1964	116306	17,0%	20593	22,9%		
1965	129019	10,9%	24676	19,8%		
1966	147878	14,6%	20881	-15,4%		
1967	156068	5,5%	21565	3,3%		
1968	176770	13,3%	23759	10,2%		
1969	194055	9,8%	27644	16,4%		
1970	217119	11,9%	27302	-1,2%		
1971	243075	12,0%	30885	13,1%		
1972	289431	19,1%	31246	1,2%		
1973	311939	7,8%	34745	11,2%		
1974	299873	-3,9%	29746	-14,4%		
1975	274804	-8,4%	25691	-13,6%		
1976	274168	-0,2%	30968	20,5%		
1977	197671	-27,9%	37634	21,5%	122017	
1978	220794	11,7%	45559	21,1%	112684	-7,6%
1979	233676	5,8%	45225	-0,7%	129088	14,6%
1980	250066	7,0%	45462	0,5%	143436	11,1%
1981	251284	0,5%	46314	1,9%	148461	3,5%
1982	253725	1,0%	48235	4,1%	131507	-11,4%
1983	247007	-2,6%	44648	-7,4%	96783	-26,4%
1984	232632	-5,8%	40412	-9,5%	91754	-5,2%
1985	226632	-2,6%	41061	1,6%	105791	15,3%
1986	221576	-2,2%	47740	16,3%	110798	4,7%
1987	228265	3,0%	56568	18,5%	123598	11,6%
1988	234634	2,8%	57815	2,2%	125666	1,7%
1989	245976	4,8%	69226	19,7%	142614	13,5%
1990	272087	10,6%	99971	44,4%	148924	4,4%

Source: Neves (1994). Note: a.a.g.r. stands for average annual growth rate.

But the general trend regarding equipment goods production has been one of stagnation, which masks wild annual fluctuations in terms of output (Table 5). Note that annual average growth rate for these sub-sectors (non-electric and electric equipment) during 1974-1990 was negative (see Table 2) but the share in total exports of the whole sector has increased from 15.6% of total exports in 1985 to 21.1% of total exports in 1993 (OECD, 1996d). In part this is due to the increasing share of the transport sector (namely multinational car producers) that is directed to export markets (Table 5 supports this growth trend during the last years).

Assessments of industrial structural change of Portugal (UNIDO, 1992) from 1980 to 1990 reveal insignificant changes in non-electrical machinery and a slight increase in electrical machinery.

In terms of the total significance of the sector the trend is a decreasing one (but so too is total manufacturing). The share of the total sector (metallic products, all machinery and transport equipment) in total output has decreased from 6.8% of GDP in 1980 to 3.8% of GDP in 1992 (OECD, 1996d).

The following tables of official statistics provide a statistical description of the whole metallurgic sector as it is nowadays.

Table 6. Main indicators of the sector in 1995.

	Metallic products	Non-electric Machinery	Electric machinery	Transport Equipment	Instruments
No. of firms	11270	2815	1188	861	418
	68%	17%	7%	5%	3%
Employment	78728	38502	46609	39831	5473
	38%	18%	22%	19%	3%
Sales	552646	326809	625748	787619	39277
(Million 1995 Esc.)	24%	14%	27%	34%	2%
Sales/employment	7,0	8,5	13,4	19,8	7,2
Costs with personnel/employment	1,6	2,1	2,5	3,0	2,0
Employment/No. of firms	7,0	13,7	39,2	46,3	13,1

Source: INE (1997). *Estatísticas das Empresas-Indústria, 1995.* Instituto Nacional de Estatística. Lisboa.

There is a large proportion of firms (68%) that are involved in the manufacturing of metallic products or structures, which, as referred above, is a somewhat permanent feature of the sector. Proportionately it is the sector that contributes more to total employment but proportionally less than the numbers of firms in the sector, reflecting the low average size of firms. It is also the one with the lower labour productivity (in terms of sales). The numbers for the sectors linked to machinery, which are those with more interest to these study, reflect the greater weight of the electrical machinery sector (on which it is included some of the heavy electromechanical industries referred above) relative to the non-electrical machinery, and the disproportion between the employment and sales of the two sectors, which in turn reflect the lower labour productivity of the non-electrical machinery sector relative to the electric machinery sector and its lower firm average size. The transport sector, in which multinational companies have an important weight, is the one with the higher productivity and also higher average firm size. Multinational firms have also a strong presence in the electric machinery sector.

In the context of a government supported programme (integrated in PEDIP; see next chapters) for the development of the equipment goods sector in Portugal Vasconcelos (1994) delimits more rigorously the sector to include only manufacturers of industrial equipment goods in a restricted sense (see Table 7) and in doing so he identifies a much more restricted number of firms. Manufacturers of tools are also excluded from the analysis. It is based on this sample, which Vasconcelos (1994) claims to represent about 90% of total sales of the equipment goods sector (in 1992) and representing an employed population of 22000 people, that he proceeds with the analysis of the (equipment goods) sector.

Table 7. The equipment goods sector; restricted sample.

Activity (manufacture of...)	Observations	No. of firms
1) Turbines, pumps, compressors, transmission mechanisms	Includes manufacture of turbines and equipment for energy production, pumps, hydraulic systems and equipment	11
2) Furnaces, burners	Furnaces and burners for various industries	8
3) Lifting and motion equipment	Includes all equipment for industrial use, lifting equipment for construction. Excludes lifts and escalators.	45
4) Refrigeration/ventilation equipment	Excludes household appliances	10
5) Packing equipment		12
6) Scales and weighing equipment	Only for industrial uses	8
7) Other machines for general use	Filtering and purifying equipment (liquids and gases), distillers, rectifying machinery, etc. Includes painting equipment.	6
8) Machines for agriculture	Includes tractors for agriculture	52
9) Metal-working machine-tools		26
10) Other machine-tools	Machine-tools for wood-working, stone-working and other materials	35
11) Machinery for extracting industries and construction	Includes equipment for crushing, concrete mixers, etc. Excludes stone-working machine-tools and lifting equipment.	19
12) Machinery for the food industries	Excludes filtering equipment, rectifiers, and exchangers.	50
13) Machinery for the textiles/garments/shoes industries		27
14) Machinery for the industries of construction materials/ceramics/glass	Equipment for manufacture of construction materials, ceramic or glass products. Excludes machine-tools.	13
15) Machinery for rubber and plastic industries	Excludes metallic moulds	6
16) Other specific machines	Includes machinery for other uses not mentioned, including machines for paper and printing industry.	22
17) Motors, transformers, and electrical equipment for distribution and control	Excludes low-tension light equipment.	23
TOTAL		373

Source: Vasconcelos (1994).

In terms of the importance of activity areas it is found that the manufacture of "Motors, transformers, and electrical equipment for distribution and control", activity 17 in Table 7, contributes to 40% of total sales, 25.7% of total employment and 41.1% of total exports of the sector, reflecting the importance of a particular group of enterprises in the sector. The second most important activity is the manufacture of "Turbines, pumps, compressors, transmission mechanisms", activity 1 of Table 7, contributing to 11.4% of total sales and 8.8% of total exports of the sector. Taken together they indicate the "...important level of specialisation of the sector in the production of electrical equipment and equipment for the production of energy..." (Vasconcelos, 1994, p.26). The next activity areas, in terms of decreasing importance are: "Machinery for the food industries", with 9.5% of total sales and 7.6% of total exports, "Machines for agriculture", with 7.9% of total sales and 5.6% of total exports, "Lifting and motion equipment", with 5.5% of total sales and 3.8% of total exports and "Other machine-tools" with 4.9% of total sales and 5.7% of total exports. It should be mentioned that the 3.3% contribution to total sales of "Metal–working machine-tools" is not proportionate to its 5.4% contribution to total exports.

The size distribution of the firms is not very different from the general pattern of Portuguese industry, i.e., almost 90% of firms have less than 100 employees. Only 3.9% of firms have more than 200 employees and only 1.5% of firms have more than 500 employees. However, total employment does not obey to this last pattern. Employment is more or less evenly distributed between firms with less than 100 employees (c. 44%), between 100 and 500 employees (c. 30%), and more than 500 employees (c. 26%). Average productivity increases remarkably (approximately two-fold) for the firms above 500 employees, but below that threshold there are no significant relationships between size and average labour productivity.

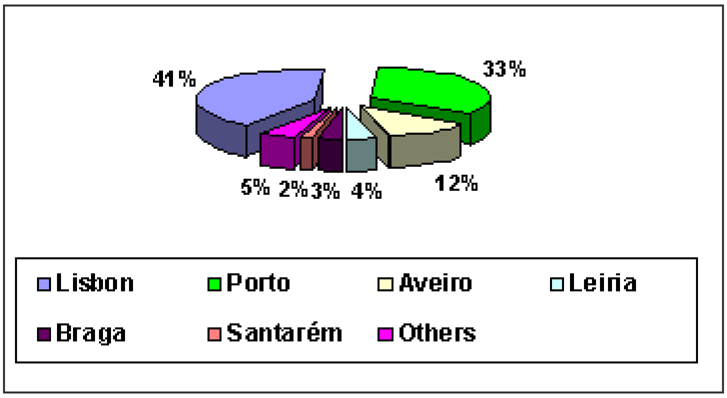
Table 8. Size distribution of firms in the equipment goods sector and its characterisation.

Size	No. of firms		Employment		Sales		Exports	
	No.	%	No.	%	Million Esc	%	Million Esc	%
<10	45	13.2	284	1.3	1753	1.0	32	0.1
10-29	123	36.0	2185	10.0	13528	7.4	820	3.8
30-49	68	19.9	2612	12.0	17363	9.5	884	4.1
50-99	65	19.0	4551	20.8	28043	15.4	2125	9.7
100-199	28	8.2	3808	17.4	22708	12.4	4684	21.5
200-499	8	2.3	2711	12.4	19045	10.4	2577	11.8
500-1000	3	0.9	1867	8.6	26000	14.2	3502	16.1
>1000	2	0.6	3813	17.5	54123	29.6	7184	32.6
Total	342		21831		182569		21812	

Source: Vasconcelos (1994).

Geographically there is an uneven distribution of firms favouring the two largest urban districts of the country (Lisbon and Porto). Other districts show up, located in the vicinity or in between the two main urban districts (Figure 1).

Figure 1. Geographic distribution of production of the equipment goods sector (% of total production by district)



Source: Vasconcelos (1994).

Geographic concentration seems to be linked or accompanied by a certain degree of geographical/regional specialisation. The most evident specialisation, in terms of the activity areas defined previously in Table 7 are as represented in Table 9.

Table 9. Regional specialisations in the equipment goods sector.

District	Activity
Lisbon	1) Turbines, pumps, compressors, transmission mechanisms ; 17) Motors, transformers, and electrical equipment for distribution and control
Porto	9) Metal-working machine-tools ; 17) Motors, transformers, and electrical equipment for distribution and control
Aveiro	12) Machinery for the food industries
Braga	13) Machinery for the textiles/garments/shoes industries
Leiria	2) Furnaces, burners ; 14) Machinery for the industries of construction materials/ceramics/glass ; 15) Machinery for rubber and plastic industries
Santarém	14) Machinery for the industries of construction materials/ceramics/glass

Source: Vasconcelos (1994).

PART II. EXPLAINING THE SYSTEM LEVEL

CHAPTER 4. INTRODUCTION

The quest for the determinants of the wealth of nations is perhaps as old as nations themselves. Throughout history several factors were decisive or crucial in determining the wealth of particular nations.

The classical school of economic thought, typified by the works of Adam Smith and Ricardo shares the same liberal principles of the early physiocrat school particularly regarding the notion of natural economic laws and the principle of freedom of economic action, but it disagrees on the identification of the source of wealth of a nation (or wealth in general). For the classical school, labour (any kind of labour) is the source of wealth and not only land or agricultural activity. The amount or type of labour involved in agriculture or any economic activity determines the productivity of the land or any other resource. Thus it is the productivity of labour that determines the wealth of nations and it is within this perspective that the division of labour and trade are analysed. Division of labour increases the efficiency of labour as well as the country specialisation.

The so-called nationalist schools of economic theory, whose most strong or known advocate is List, attack the universal and individualistic nature of economic activity proposed by the classical school. Against the classical reasoning that assumes that the wealth of a nation is only the sum of the wealth of the individuals, List opposes the concept of the nation as an intermediary between the individual and the human genre, and that what counts more is not wealth in itself but the potential to create wealth. As a corollary not all economic activities/sectors are considered equally conducive to wealth creation unlike the assumptions behind the classical framework which do not discern between the wealth creation effects of different sectors of activity (only different kind of labour). The nationalist school cherishes the notion of "productive forces" to distinguish between those sectors of the economy that are potential multipliers of wealth.

The last two approaches analysed the role of technical change in economic development, each one according to its own theoretical principles. The classical school does not explicitly emphasise the role of industry in economic development and offers little in the explanation of the determinants of technical change. However, Adam Smith proposed the idea that the division of labour is a direct cause of inventive activity, distinguishing between earlier and later instances in the state and sophistication of the division of labour:

> “A great part of the machines made use of in those manufactures in which labour is most subdivided, were originally the inventions of common workmen, who, being each of them employed in some very simple operation, naturally turned their thoughts towards finding out easier and readier methods of performing it...[...] All the improvements in machinery, however, have by no means been the inventions of those who had occasion to use the machines. Many improvements have been made by the ingenuity of the makers of machines, when to make them became the business of a peculiar trade; and some by the that of those who are called philosophers or men of speculation, whose trade it is not do anything, but to observe everything; and who, upon that account, are often capable of combining together the powers of the most distant and dissimilar objects” (Smith, 1970, p. 114-115)

The nationalist school gives explicit attention and importance to science and technology and its impact on industrial and economic development, but advances little, although it tries hard, in the way of explaining the mechanisms underlying the process of innovation.

Karl Marx addresses the determinants and dynamics of technical change and industrial innovation in much more detail. He devotes an extensive chapter in the first volume of the Capital to the analysis of machinery and the development of machinery in industry and its implications on labour. The analysis of Marx (1979, first published 1867) is of course a critique of the capitalist system. He argues that what is behind the development of machinery is the exploitation of the "relative surplus value" arising from labour: "Machinery produces relative surplus-value...reducing the value of labour-power" (p.530). In addition to this general rule, Marx suggests specific determinants of technical change. As such, he makes the development of machinery and the innovation process endogenous to its analysis of the economic system. The main determinant of technical change is linked to the benefits that capital extracts from lesser dependency on labour, but it is not the sole:

> "The object of improved machinery is to diminish manual labour, to provide for the performance of a process or the complementation of a link in a manufacture by the aid of an iron instead of the human apparatus...The adaptation of power to machinery heretofore moved by hands is almost of daily occurrence...the minor improvements in machinery having for their object economy of power, the production of better work, the turning off more work in the same time, [...] and although sometimes of no great moment, have somewhat important results."(p. 559)

It is interesting to note that Marx already notices the very important long-term cumulative effects of small improvements anticipating recent theoretical considerations about the typology and the impacts of innovation (Freeman and Perez, 1988). He is also aware of the cumulative and systemic features of the process of innovation and its implications for economic growth, for the patterns of economic cycles and for the international division of labour. Marx's analysis is paramount insofar as it places technology at the centre of the process of economic change unlike the classic school of economics (of which Marx is very critical) that at most gives sparse attention to the subject and treats technology in a rather exogenous manner.

Rosenberg (1994) argues that Marx has an intellectual indebtedness to Babbage's works on the relationship between technology and the economy ("On the

Economy of Machinery and Manufactures", first published in 1833, as cited by Rosenberg, 1994): "... Babbage's influence on Marx is [...] pervasive, as would be revealed by a close textual comparison of Babbage's treatment of the causes and consequences of the division of labour with that of Marx..." (p.43). Rosenberg notes that the emphasis of Marx is different: "...Much of Marx critique of capitalism flows from examining exactly those characteristics of the division of labour that Babbage identified as sources of improved efficiency in the factory. However; Marx considers them from a very different perspective...from the point of view of the welfare of the worker." (p. 44)

Rosenberg argues that Babbage provides one of the earliest accounts of the determinants of technical change and inventive activity. The combination of Babbage's own technical skills and inventiveness and his interest on economic issues explains the prominent role that technology acquires in his works unlike the purely theoretical treatment of social scientists. The author notes that the analysis of Babbage takes into consideration a set of economic factors broader than that of Marx:

> "It is also worth noting that Babbage shows an acute awareness of the economic forces that drive inventive capability in specific directions and that influence the timing of inventive effort. In fact his observations deserve to be regarded as possibly the earliest treatment of the economic determinants of inventive activity. [...] It seems to be a reasonable claim that Babbage is the first observer of the events of the industrial revolution to call attention in an explicit way to the causal links between economic forces and inventive activity." (p. 32-33)

The theoretical confrontation and differentiation between the schools mentioned above continued throughout the 20th century. The classical school evolved into the so-called neo-classical marginalist school and the nationalist and Marxist perspectives are included in the broader historical schools which is often in direct confrontation with the other schools. At the risk of over-simplifying one can say that these are the two streams of economic thought that nowadays are most influential in terms of intellectual impact.

The historical school was born out of the difficulty that some authors expressed in accepting the limits on the economic science draw by the classic English and French authors and their abstractions and generalisations. The historical schools argue that the economic structure of defined social groups (such as nations) is in constant transformation, going through some well-defined and successive stages of development. This notion is in contrast with the universal and fixed character of the economic laws proposed by the classical (and later the neo-classical) school.

Schumpeter (1939) is the early 20th century's most notable author within the historical school that places science and technology at the centre stage of economic development. The theoretical framework of Schumpeter challenges established classical/neo-classical concepts such as the desirability and assumption of perfect competition, perfect information and general equilibrium. Schumpeter argues that the constant stream of innovations that are produced by the capitalist system heavily determines the process of economic development. Science and technology are treated as endogenous factors and the economic reality is treated within an organic (evolutionary) and not mechanistic (equilibrium) perspective:

> "The opening up of new markets, ...and the organisational development from the craft shop and factory to such concerns...illustrates the same process of industrial mutation – if I may use the biological term – that incessantly revolutionises the economic structure from within, incessantly destroying the old one, incessantly creating a new one. This process of Creative Destruction is the essential fact about capitalism." (Schumpeter, 1947, p.83)

Schumpeter criticises explicitly the mainstream neo-classical theoretical framework and emphasises innovation, dynamic factors and desiquilibrium as the main characteristics of the process of economic development:

"As a matter of fact, capitalist economy is not and cannot be stationary. Nor is it merely expanding in a steady manner. It is incessantly being revolutionised from within by new enterprise, i.e., by the intrusion of new commodities or new methods of production or new commercial opportunities into the industrial structure as is exists at any moment. Any existing structures and all the conditions of doing business are always in a process of change. Every situation is being upset before it has had time to work itself out. Economic progress, in capitalist society, means turmoil." (Schumpeter, 1947, p.31-32)

The work of Schumpeter highlighted the conflict between the two intellectual traditions mentioned above. Reinert (1995) expresses this conflict, in the context of the discussion of the determinants of the wealth of nations, in the following way:

"An important problem facing the standard economic theory of today is that the countries which grew rich did so in the wrong way. In the neo-classical world, additional wealth is supposed to spread through lowered prices...However, as technology progresses a nation can get rich in two very different ways. One is the mechanism suggested by Smith and Ricardo; technological change only causes prices to fall. The other way, which is not discussed outside the field of labour economics, is that an important portion of the benefits from technological change is being distributed inside the producing nations through higher profits, higher wages, and higher taxable income overall [...] When the first mechanism operates the benefits of technological change are spread exclusively to the consumers of goods produced. When the second mechanism operates, the producer (company and nation) of goods retains an important part of the benefits of improved productivity." (p. 27)

Schumpeter's work also contributed to foster new intellectual efforts that explicitly include technology as an essential factor and determinant of the wealth of nations. One of its merits, recognised in Dosi et al (1988), is "...his constant emphasis on innovation as the main source of dynamism in capitalist development, his sense of historical perspective, his recognition of the importance of the conceptual distinctions between invention, innovation and diffusion of innovations, and his recognition of the vital importance of the links between organisational, managerial, social and technical innovations." (p.5).

Recent theorising on economic theory tried to account for the perceptions or perspectives advanced by Schumpeter and to express alternatives to the neo-classical economic theory. The so-called neo-Schumpeterian or evolutionary theories of economic change (Nelson, 1982, Clark and Juma, 1987, Saviotti and Metcalfe, 1991) propose, as the name says, an evolutionary perspective instead of the mechanistic perspective involved in the neo-classical theory. Both schools of thought have recognised the endogenous nature of technical change (see Thirtle and Ruttan, 1987, or Verspagen, 1992, for reviews of the neo-classical school) but the neo-classical construct remains a mechanistic and restricted one. Evolutionary theories include the following general characteristics:

> "The focus of attention is on a variable or set of them that is changing over time and the theoretical quest is for an understanding of the dynamic process behind the observed change; a special case would be a quest for understanding of the current state of the variable or a system in terms of how it got there. The theory proposes that the variable or system in question is subject to somewhat random variation or perturbation, and also that there are mechanisms that systematically winnow on that variation. Much of the predictive power of that theory rests with its specification of the systematic selection forces. It is presumed that there are strong inertial tendencies

> preserving what has survived the selection process. However, in many cases there are also forces that continue to introduce new variety, which is further grist for the selection mill" (Nelson, 1995, p.54)

Evolutionary theories stress the notions of path-dependency, co-evolution, variation and selection. These notions can be applied either at technology, firm or institutional level, to explain how a specific technology, firm or institution shows the characteristics that it has at a certain point in time. It is a relatively easy step to extend the object of analysis to nations and to try to explain the wealth of a nation using evolutionary arguments.

Having recognised the fundamental importance of technological change and other forms of innovation (organisational or managerial) as a crucial factor behind economic development, and having established a theoretical framework that accommodates differences in the economic situation of countries, there has been recently a new approach, known as "Systems of Innovation" and sometimes also "Systems of National Innovation", that tries to explain the mechanisms that turn technological change and innovation into increased economic gains and performance at the level of the nation. Saviotti (1997) argues that the foundations of such an approach rest on the complementary of five disciplines/research traditions, only one of which is connected to evolutionary theories of economic change. The disciplines/research traditions are systems theory, non-equilibrium thermodynamics, biology, organisation theories and economic antecedents of evolutionary theories. Taken together they constitute the theoretical justification of the approach, inasmuch as it "...predicts structure formation, qualitative change, indeterminacy, irreversibility, path dependence and multistability, properties that are commonly displayed by National Systems of Innovation" (Saviotti, 1997, p.182)

Earlier, Clark and Juma (1987) also stressed the theoretical background provided by the thermodynamics discipline and the implications in terms of "irreversibility" and "self-organisation" of a system and its applications to the study of the dynamics of technological systems.

Freeman and Soete (1997) claim recognition for List's earlier attention to national innovation systems: "Not only did List analyse many features of the national system of innovation which are at the heart of contemporary studies (education and training institutes, science, technical institutes, user-producer interactive learning, knowledge accumulation, adapting imported technology, promotion of strategic industries, etc.) He also put great emphasis on the role of the state in co-ordinating and carrying through long-term policies for industry and the economy." (Freeman and Soete, 1997, p.298)

Lundvall's (1992) book represents a major advancement in terms of the theoretical formulation of the theory already previously sketched in Lundvall (1988). The author argues that a successful process of innovation is heavily dependent on user-producer interactions and specifically on the competence of the interacting parts and on the strength of the interaction. He also suggests that a nation is a somewhat privileged framework for user-producer interaction (notwithstanding international relationships) because of cultural, political and other institutional similarities that facilitate or make more economical the interaction process.

Porter (1990), who comes from the theoretical perspective of the management school, proposed also an analysis based on the interaction of several dimensions within one nation. He uses the term "diamond" to refer to the determinants of "competitiveness" of a nation as a system. The determinants are classified in four broad categories: 1) factor conditions: the nation's position in factors of production, such as skilled labour or infrastructures, 2) demand conditions: the nature of home demand, 3) related and supporting industries: the presence or absence in the nation of supplier industries and related industries, and 4) firm strategy, structure and rivalry: the conditions in the nation governing how companies are created, organised and managed, and the nature of domestic rivalry. The complex and systemic interactions between these broad set of factors determines then the performance and the so-called "competitiveness" of a nation, whereby the term "competitiveness" of a nation is derived from the notion of competitiveness at the level of the firm (for a discussion see Georghiou, L. and Metcalfe, J. (1993) and Reinert (1995)).

Nelson's (1993) work is another addition to the "National Innovation Systems" approach. It presents a collection of case studies and tries to compare and analyse the differences between the different nations. There is a set of characteristics that is common and centre stage to all studies. Learning is the main phenomenon that is stressed. Its various dimensions, as identified by several authors, are worked upon: learning by doing (Arrow, 1962), learning by using (Rosenberg, 1982) and learning by interacting (Lundvall, 1992). OECD (1992c) even refers to learning by learning, to remind that in order to learn you have to possess some pre-requisites, i.e., some absorptive capacity. Aside from this central emphasis, the following characteristics are also common (Edquist, 1997): the approach is holistic and interdisciplinary, it is historically oriented, the differences in the systems are focused upon rather than abstracted from, it emphasises interdependence and non-linearity, it involves product as well as organisational innovations and the institutions are central to the analysis.

The recent focus on learning processes coming out from these and other studies of systems of innovation implies a focus on information flows rather than individual inputs or outputs of the system:

> "Systemic approaches are giving new insights into innovative and economic performance in the OECD countries. Technology-related analysis has traditionally focused on inputs (such as research expenditures) and outputs (such as patents). But the interactions among the actors involved in technology development are as important as investments in research and development and they are key to translating the inputs into outputs. The study of *national innovation systems* directs attention to the linkages or web of interaction within the overall innovation system."(OECD, 1997a, p.3)

As a consequence the measurement of traditional inputs (such as R&D expenditure or R&D personnel) and outputs are now seen as an insufficient source of information of the whole system because they fail to provide an adequate picture of the inner workings of the system (asides from being a rather static picture of it). Recent studies are trying to systematically probe the interactions within the system and to develop indicators that are appropriate to capture the dynamics and the interactions of the system. Examples of such studies include research on industry alliances (e.g. Hagedoorn and Schakenraad, 1990), innovation surveys (e.g., OECD, 1992d and 1997), the type and the dynamics of relationships between firms (Swann, 1996) and firm surveys among others.

The following chapters are an attempt to describe and to understand what are the systemic influences on the dynamics of technical change in Portuguese society. The (Portuguese) system is arbitrarily divided into three sub-systems and the interactions and reciprocal influences between the sub-systems, whose perceived impact on technical change are seen as important, will be discussed. The statistical information is not extensive, nor, for that matter, is some of the qualitative information, especially in terms of information flows between the several actors of the system. Consequently many statements are based on deductive exercises and their nature is rather hypothetical, others are corroborated or supported by empirical evidence discussed in the next part of the thesis. The choice of topics, issues and characteristics of the system that were included in its description and subject to analysis represent those issues that were identified as potentially important and with a higher potential in terms of explanatory power. In this work, the proposal of Edquist (1997) is followed, as it concerns this choice:

> “In addition, none of the major authors provide a sharp guide to what exactly should be included in a (national) system of innovation; they do not define the limits of the system in an operational way [...] both Nelson and Lundvall explicitly state that the boundaries are unspecific. My own proposal is subject to our ability to identify the determinants of innovation...[...] However,

it might be an impossible task to identify the boundaries in detail...[...] An important complement to these attempts at specification is then to try to identify the core elements in systems of innovation, and focus on the relations between these..." (p. 27)

CHAPTER 5. THE EVOLUTION OF THE ECONOMIC ENVIRONMENT

5.1 The industrial revolution

Portugal was a latecomer to the industrial revolution. It was indeed very late in coming to the industrial revolution, according to what is known today about the subject and compared with other developed European countries on the forefront of the industrial revolution (UK, Belgium, France, Germany, Switzerland, etc.) or even with other latecomers such as Japan, or Russia.

The question of the retardation of Portugal in developing a modern industrial structure has been the subject of numerous and long-dated concerns. More recently several studies tried on a more systematic basis to find the causes of such retardation (Pereira, 1983, Serrão e Martins, 1978, Cabral, 1976, Castro, 1973, Serrão, 1980, Castro, 1978) and have provided a wealth of quantitative and qualitative information about the evolution of the system during the last centuries. Even more recently, there were new attempts to conceptualise and organise the information retrieved so far and to estimate quantitative long-series data for the mentioned period (Nunes et al, 1989, Reis, 1993, Lains, 1995) and new hypotheses have revived the debate.

The differential between Portugal and other developed countries became more acute after the second half of the XIX century. This historic period was for many countries a time of rapid growth and industrialisation. Portugal was also involved in that expansion but its rate of growth was slower than other underdeveloped countries growth rates or just equal to the developed countries growth rates. Just before the start of the 1st World War the difference in GNP per capita between other developed countries was "... greater than ever" (Reis, 1993). Table 10 represents the situation.

Table 10. GNP per capita of Portugal as a fraction of GNP per capita of other countries.

	1860	1913	1950	1975	1994[1]
Germany	77%	37%	41%	34%	32%
Denmark	93%	34%	31%	36%	31%
France	75%	42%	33%	32%	38%
UK	47%	29%	28%	49%	50%
Italy	92%	66%	65%	59	49%

Source: Bairoch (1976) as cited in Reis (1993).

1) Source: OECD (1996d)

The distance that separated Portugal from other countries was not substantial in 1860 with the exception of the United Kingdom by then the most advanced industrial nation. Between 1860 and 1913 the distance increased dramatically, as reflected by the ratio of GNP per capita of Portugal to the GNP per capita of a group of developed countries. That inequality has remained until the present day and the differential even increased although it did not became significantly greater.

By the end of 1910 Portugal compared rather badly in terms of economic development with other European developed countries as some of the usual indicators show (Table 11).

Table 11. Indicators of economic development in 1910.

	Portugal	Europe
GNP per capita (1960 US$)	290	499
Population in cities greater than 5000	17%	36%
Cotton consumption (Kg per capita)	2.97	5.81
Spindles per 1000	80.6	237.0
Iron consumption (Kg per capita)	11.1	80.0
Coal consumption (Kg per capita)	200	1509

Source: Reis (1993).

Reis (1993) argues that there are essentially three theses that emerged in the literature about the causes of Portuguese industrial sluggishness. According to one of them the problem lay in the external dependence of Portugal, namely as regards raw materials and access to energy sources and particularly in the dependence of Portugal upon Great Britain. In the absence of protectionist tariffs (a measure supposedly imposed by the UK) Portugal specialised in primary products and imported a great deal of manufactures thus crippling its industry and compromising its opportunities for growth via industrialisation. Pereira (1983) concludes that "... the history of Portugal during the second half of the XIX century illustrates the case of the countries whose industrialisation was blocked by the United Kingdom" (p.315). The thesis, however, raises problems of incongruity with available data. On the one hand exports were not a significant part of GNP at the time (total exports represented 3% of GDP in 1842, 5.1% of GDP in 1870 and 3.2% of GDP in 1890; source: Mata, 1994) and on the other hand Portuguese tariffs during the second-half of the XIX century were among the highest in Europe placing the country in the protectionist "club" of which the USA is the paradigmatic example (Table 12).

Table 12. Import duties as a percentage of import value.

	United kingdom	Portugal	USA
1855-1865	11.2	29.8	22.2
1865-1875	6.6	26.6	37.5
1875-1885	5.0	29.6	29.7
1885-1895	5.0	31.1	26.6
1895-1905	5.3	28.3	25.5
1905-1913	5.0	27.2	21.4

Source: Reis (1993).

A second thesis argues that the underdevelopment of Portuguese economy was due to the land ownership structure of the country inherited from the old regime (the so-called Absolutist regime, a very conservative regime in place until 1820) subsequently subject to restructure after the so-called liberal reforms (post-1820) of the first half of the XIX century, but one which resulted in an excessive concentration of property in the South of the country and an excessive fragmentation in the North of the country. The impact on development of this structure lay on the one hand in the lack of motivation of the large landlords of the South to invest in industrial projects because they could extract big profits from the land even if irrationally or inefficiently explored, and on the other hand, on the incapacity, on the ignorance and on the fragility of the economy of subsistence of the small peasants which constituted the majority of the population on the North and its subsequent inability to generate sufficient demand conditions for the creation of investment capital. Or, in other words, the process that Pollard (1990) refers to: "… more wealth flowed into the hands of the investing middle classes rather than the spending landed or poorer classes…" found difficulties in occuring. The counter-argument against this thesis is that there are instances that similar structures (either excessive concentration or excessive fragmentation) did not prevent increases in productivity (Chorley, 1981). The obstacles associated with the lack of progress in the agricultural sector may be related to other factors such as lack of technical support, social tensions deriving from the adoption of machines and the cost structure associated with economies of scale (Reis, 1982).

Finally the third thesis (Cabral, 1979, Serrão e Martins, 1978) finds the causes in the social and cultural structure of Portuguese society, blaming its class rigidity, the weakness of the middle-classes and a state dominated by a social group with vested interests in import-export activities: The critique usually made to this thesis is that it does not go deep enough into the causes of that state of things and it does not satisfactorily explain why the actors acted as they did, given the circumstances.

All these theories are not mutually exclusive and all contain a piece of the puzzle. Cabral (1978) mixes elements of the second and third theories when he tries to explain the dynamics of the industrial revolution or more accurately the dynamics of the introduction of the capitalist mode of production (the analysis is heavily grounded in

Marxist theories) using social groups as the units of analysis. Roughly speaking, he argues that the middle-class, or the "bourgeoisie" was divided in two main conflicting blocks: one linked to merchant activities and agriculture, whereby the United Kingdom and the overseas colonies are the main destinations or sources, and the block linked to production activities, namely manufacturing. The antagonism between the two blocks was more acute in questions like protective tariffs (the merchant block was against tariffs because it made their products more expensive and the production block was in favour because it could not compete in terms of price, or for that matter in terms of quality and characteristics, with foreign products) and the building of physical infrastructure (for which the merchant block, which relied on transport by sea, saw no apparent or worthy benefit). This theory is now seen as an oversimplification and does not capture all the complexity of the problem. In a sense it is contradicted by the facts, such as the high import duties that places Portugal definitely alongside the protected. On the other hand, a finer analysis of the diversity and features of the products that were really under tariff protection may after all allow some space for the theory (because not all products were subject to protection) or it may even allow space for other theories that recognise a cohabitation, although not always peaceful, between the two blocks. It seems, for instance, that capital goods were not subject to import duties as heavy as those for other consumer goods such as textiles. Within the textiles category the level of protection depended on the fact that the product was manufactured in Portugal. In the case of machinery, since many of the machines were not manufactured domestically, the duties were generally low, which apparently had perverse effects on the indigenous development of a capital goods sector. For this author, the second half of the 18th century represents a period of transition from a feudal regime to a capitalist regime. He stresses the coexistence of both structures in the same historical period and analyses the transition from a socio-economic perspective characterising the power and interests of each social class/group and the confrontations that arise from conflicting interests and intentions. He argues that the conditions for a full-fledged capitalist mode of production are definitely in place when the last remnants of the feudal land ownership structure of the country are finally abolished by the end of the first third of the 19th century (a process that started after the liberal revolution of 1820) thus putting, as a way of speaking, the land in the hands of the market and allowing for its mobility. The mobility of the land was particularly accelerated after the liberal revolution due to one important event, the nationalisation and subsequent public auction of the land and property of the church. The wealth of the church was enormous. It is estimated that the total value of the church property immediately before 1820 included hundreds of buildings and one third of the total national arable land. It was believed that the event contributed to increase the productivity of the land and to increase production and trade (Saraiva, 1978).

The laws that regulated the economic activity of the country were marked by strong feudal characteristics including, among others: the impossibility to alienate some lands from their ancestral owners, the succession rights that imposed the eldest son as the heir of all the property and did not allow the fragmentation of the land among the other progeny, the laws that stubbornly perpetuated a system with many characteristics of a serfdom, the local taxes, different from region to region, raised by the landlords, the church, and the county that suffocated the landed or landless small peasant or the small artisans and craftsmen, internal tolls falling on the circulation of goods and people and taxes charged over export activities. The liberal revolution of 1820 (see below) marked the beginning of the crumbling of this legal structure but its complete replacement by another legal framework would take fifty years.

It is generally accepted (Macedo, 1982) that during the second half of the 18th centurt the state gave priority to the development of the industrial structure. But the result of that development was more quantitative (i.e., more “industrial” units came into existence) than qualitative (i.e., the methods of production remained essentially unaltered). It should be noted however that this quantitative development is not without importance since by increasing the share of population employed in the secondary sector it influenced the future establishments of national priorities or at least awareness of the need to increase wealth by means of industrialisation. Matos (1996) refers the establishment of factories-schools during the second half of the 18th century whose objective was to be models of excellency so as to demonstrate, to propagate and to induce imitation of the methods employed on them.

Pereira (1991) argues that the calico-printing industry is one of the first (if not the first) sub-sectors of the textile industry in Portugal to acquire modern industrial characteristics during the second half of the 18^{th} century. He particularly refers to the large dimensions of the so-called "proto-factories", aggregating workforce and processes in very large workshops. The development of the factories seem to be a direct consequence of the industrial policy of the time and were supported in several ways by the state (financially, tariff barriers and tax exemptions). The backwardness of Portugal was already evident at the time. Lisbon was one of the few seaports linked to Oriental trade that does not establish calico-printing factories at the beginning of the 18^{th} century. Its introduction had to wait until 1775 with the mentioned help from the state, which was, by the way, interested in establishing more than the calico-printing industry and was in fact putting pre-conditions for its establishment, namely that the new factories should also embark in the weaving business (requisites that were not really imposed). The business was dominated by merchants' capital, on one hand, and the artisan or craftsman on the other. Most of the tissue was imported, printed in the factories and then sold internally or exported.

At the time the economy was, in many ways, dominated by an elite of merchants, the capitalists of the epoch (linked to export-import activities and the so-called state monopolies such as tobacco, but also to credit activities, land exploration and speculation, and many other activities) and the calico printing industry was an opportunity among others to add extra value to their diverse activities, and they were particularly well placed in the business flow since they imported and exported many kinds of textiles. We can say that there is a process of vertical integration of commerce with industry. The funds they provided needed, however, the technical skills of the craftsmen many of whom were foreigners and who later established their own factories.

The presence of foreign technicians (particularly British, but also French and Belgian, to cite only the more common nationalities established in Portugal) is another recurrent theme of the process of industrialisation process of Portugal. Behind the introduction of new industries or new products one is almost sure to find a foreign name. This fact is true for the 18th, the 19th (and also to the 20th century, although it is a process with different contours) which is an evidence of the persisting technological dependence of the country, but also of its efforts to "stay in touch". In spite of the presence of foreign technicians, many of the factories were backwards compared to their analogue in Europe. Apparently there were no efforts to turn endogenous the expertise of the foreigners who, naturally, explored their skills for their own profit, often recurring to secrecy. Many phases of the process were made manually and with no chemical aids. Printing with cylinders was introduced in 1800, and the steam engine, allowing the introduction of colour machines was only introduced in 1847 (Pereira, 1991).

One can advance several ideas about the factors affecting the slow rate of the industrialisation process at this time, asides from (but also building on) the general arguments put forward above. First, although the merchants played an important role in providing finance for the endeavour (and this is a factual counter argument against a dualistic structure of a middle-class composed of a "conservative" component linked to export-import activities and the "progressive" component linked to manufacture), they lacked a feeling for the business (it was just another one in their portfolio, and one on which they had to divide control with the technical experts) and what they wanted was quick turnover and profits (more like a commercial activity). No real importance was attached to strategic factors like the appropriation of the technology embodied in the foreign craftsman. Second, in spite of its technical backwardness the sector contributed to the introduction, establishment and diffusion of large factories with relatively complex logistics and a fairly sophisticated division of labour. Third, it was the start of a process of industrial concentration which later gave place to a process of vertical integration with other textile sub-sectors (spinning and weaving, particularly weaving), although the printing sector remained relatively autonomous until quite late in the 19th century.

One reason often mentioned for the late industrialisation of Portugal was the absence of social or civil stability particularly during the 1st half of the 19th century. Cabral

(1981) links the restlessness to the dynamics of change of regime to a capitalist mode of production (see above). The transition was slow because the conflicts were not, in many cases, radicalised. The truth is that civil unrest occurred frequently after 1820 and before that there was turbulence and destruction brought by the Napoleon invasions of the early 1800s. Some authors argue that the ideological influence of the French regime and invasions accelerated or accentuated and inspired the need for change (Saraiva, 1978). The so-called Liberal Revolution introduced a democratic system in place of a regime based on the absolute power of the monarch (but the regime remained a monarchy, a parliamentary one). The unrest lasted until around 1850 where finally a relatively long period of social peace and stability ensued (more or less until 1910). The chronology of the events is given in Table 13, involving a first period marked by the confrontation between the partisans of the old pre-1820 regime (the “Absolutists”) and the “Liberals” and a second period involving confrontations between the radical and conservative factions of the Liberals.

Table 13. Changes of political regime or changes in government involving a break in the pre-existing law and main failed attempts with the same aim in Portugal: 1820-1851.

Characteristics	Date	Place	Result	Comments	
Liberal Revolution	24-8-1820 15-9-1820	Porto Lisbon	Successful	1	
Absolutist Revolt (moderate faction)	27-5-1823	Lisbon	Successful	2	
Absolutist revolt (radical faction)	30-4-1824	Lisbon	Unsuccessful		
Military coup d'état	31-7-1826	Porto	Successful	3	Confrontation between the "Liberals" and "Absolutists" (old regime)
Absolutist revolts-civil war	1826-1827	Several	Unsuccessful		
Absolutist Restoration (radical faction)	26-4-1828	Lisbon	successful	4	
Liberal revolt	May-Jul. 1828	Porto	unsuccessful		
Liberal revolts-civil war	1828-1834	Several	successful	5	Final defeat of the old regime
Liberal radical coup d'état (start of the period known as "Setembrismo")	10-9-1836	Porto Lisbon	successful	6	
Liberal conservative coup d'état	3-11-1836	Lisbon	unsuccessful		
Liberal conservative revolt-civil war	Jul.-Sept. 1837	Several	unsuccessful		
Liberal radical revolt	13-3-1838	Lisbon	Unsuccessful		
Liberal conservative coup d'état (Start of the period known as "Cartismo")	9-2-1942	Porto	Successful	7	Confrontations between the "Liberal" factions
Democratic revolt	4-2-1844	Torres Novas	Unsuccessful		
Popular mutiny (Maria da Fonte)	Apr.-May 1846	Minho	Successful	8	
Liberal radical revolt-civil war (Patuleia)	Oct.1846-Jun.1847	Several	unsuccessful		
Liberal radical coup d'état (Regeneration)	1-5-1851	Porto	Successful	9	

Source: Mata (1991).

Notes:

1) The kings were replaced and most of their power transited to an elected parliament that approved a new Constitution in 1822.

2) The Constitution of 1822 was abolished and it was initiated the elaboration of a new Fundamental Document of the Nation (the Carta Constitucional) by the absolutist government that returned much of the power to the Monarch.

3) The Carta Constitucional is approved by the Queen of the moment.
4) His brother that was supported by the more radical faction of the absolutist movement replaces the King and the Carta Constitucional is put aside.
5) A very violent period with widespread civil war. The conservative wing of the liberals wins and replaces the King and reinstates the Carta Constitucional.
6) The moderate wing of the liberal faction replaces the Carta Constitucional by the more radical (and democratic) Constitution of 1822.
7) The Carta Constitucional replaces again the Constitution of 1822.
8) Mutiny led to fall of government.
9) Elections for a new Parliament that modified the Carta Constitucional. After this event it follows a relatively long period of stability.

Finally, after 1850, a compromise was found and the two factions agreed on the Constitution letter and on a scheme that alternated the two factions in the government.

In spite of the restless nature of the period it is in the first quarter of the 19th century that an increasing social awareness and preoccupation with industrial developments begins to translate in more palpable civil actions. Among them is the creation of professional associations whose objectives included the promotion and diffusion of technological knowledge and its economic application. These new societies/associations created after the Liberal Revolution of 1820 differed from earlier scientific societies created at the end of the 1700s in the sense that they were more concerned with the application (and diffusion) of knowledge for the sake of wealth creation and not only with purely scientific and intellectual motivations.

As Table 14 shows the number of associates is extremely small (total population in 1830 was approximately 3.5 million and in 1890 approximately 5.5 million) and they were concentrated in Lisbon (specially) and Porto, the two largest cities. The list in Table 14 is not exhaustive but it represents a very representative sample (Matos, 1996). This panorama reflects another recurrent theme of Portuguese industrialisation, which is the lack of diffusion of technical and scientific capabilities throughout the country, a problem that has persisted until today. These two main population centres (and Lisbon above all) have always concentrated a (very) disproportionate share of the physical and human scientific and technological capital.

Table 14. Date of creation of some associations and number of associates.

Name	Date	Number of associates
Sociedade Promotora da Indústria Nacional	1822	
		756
Associação Industrial Portuguesa	1837	
		76 (in 1852)
Associação Industrial Portuense	1851	344 (in 1856)
Associação Promotora da Indústria Fabril	1860	183 (in 1868)

Source: Matos (1996).

Nevertheless the associations were instrumental in several ways. Their greatest efforts were in the diffusion of knowledge by several means. Most of the associations initiated the publication of technical periodic magazines that gave notice of scientific or technical books recently published and translated foreign articles that they considered relevant for the Portuguese industry. Some of them also set up their own libraries with books purchased by the association or offered by the associates or others altough their success (in terms of visits) seemed not to be very great.

The associations promoted actively the realisation of periodic industrial fairs or expositions whose character could be local, regional, national or international. The first formal national event of this type was apparently in 1845 (Matos, 1996) although Serrão (1980) dates it to 1838 but there were earlier instances of informal shows of national industrial or agricultural artefacts since 1827. During the second half of the 19th century the events became more regular and the associations begun to send their members abroad to participate in European fairs or expositions. Other activities of dissemination of technological knowledge included the realisation of demonstration actions of imported machinery.

The associations were also active in educational activities being responsible for the implementation of some of the first technical courses and lobbying strongly for the implementation of technical schools, a matter to which we shall refer in more detail in another section.

We shall open a parenthesis here to say that the more active members in these associations were also very active in political terms and there are many instances of members of government and members of parliament who were active associates. So the evolution of national priorities in the development of industry and the development of indigenous technical capacity can be partially assessed by looking at the activities and objectives of these associations. Another remark is that the scope of the term “industry” at the time was wider than its current meaning today, including not only the manufacturing sector but also the agricultural sector and even the services sector, at least until 1840 when the meaning of the term seems to have stabilised on its present form. Even so and given the social momentum embedded in the social values behind a collective endeavour such as a professional association we expect that the multivariate sectoral concerns of those associations will last longer than the change of meaning of the word.

One important contribution that this intermingling between professional associations and government produced was the systematic collection of industrial data that started around 1841, after the creation of a specialised institution with that function. The Industrial Census of 1881 (Ministério das Obras Públicas, 1881) seems to be the first reliable set of industrial statistics and it also contained a great deal of qualitative information (descriptions of the surveyors and observations of the industrialists) which made this survey the main source of information for students and researchers of Portuguese industrial development and history.

Based on the industrial census of 1845 Serrão (1980) identifies a surge in industrial activity by the year 1836 (based on the number of surviving industrial units established in a particular year) and associates it with the definite establishment of the liberal regime in 1836 (and the period that followed, the so-called “Setembrismo” that ended with the so-called “Cartismo”; see Table 13) and its policy of industrial support by means of tariff protection. Bonifácio (1991) argues that the revitalisation of industry was due to the following period (the “Cartismo”) characterised by greater stability and equal tariff protection. The author, based on the industrial census of 1845, takes a look at the products manufactured at the time, verifying their poor quality, the traditional manufacturing processes still employed and the diminutive number of large factories, i.e., it confirms a general picture of backwardness advanced by other authors. According to manufacturing statistics of 1814 (Castro, 1978) industrial output consisted mainly of traditional consumer goods such as textiles, of the most crude type according to Bonifácio (1991), leather products, ceramics, paper, cutlery and other metallic structures, calico-printing, foodstuffs and chemically derived consumer products (soap, detergent). Bonifácio (1991) confirms the general portfolio of the Portuguese industrial product in 1845, deducing from the list of products that were to be protected by tariffs the (little) diversity and (poor) quality of the industrial product. However the production of steam engines (in 1848) is already noted by several authors (Bonifácio, 1991, Serrão, 1980, Matos, 1991). Serrão (1980) refers to the presence of Portuguese-made machines in the industrial fair of 1848.

The steam engine was introduced quite late in Portugal. Castro (1978) estimates 1835 as the year steam engines were first applied for industrial manufacturing purposes, deriving his conclusions from cross-comparisons of dispersed data. Serrão (1980) describes the first attempts to introduce the steam engine in Portugal, the first demonstration dating from 1742. There was an attempt by a powerful industrialist to apply the steam engine to the food-milling sector during the 1810s but its demands for excessive monopolistic concessions and the consequent protests from competitors terminated the attempt.

The steam engine was first introduced in the transport sector namely in sea transport, by the year 1821. Due to the very poor existing road infrastructure a great deal of domestic trade (and passenger transport) was done by sea (by sailing ships along the coast) and the economic viability of the steam ship was confirmed since the first moment of operation. Besides the cargo services by 1823 there were already regular passenger lines between Lisbon and Porto. By 1870 traffic by sailing vessels had declined due to the competition with the steam vessels. It is thus by this way that the steam engine insinuates itself in Portugal. Probably they were the main locus and source of technical tacit learning for the would-be manufacturers described above and other technicians.

Table 15. Diffusion of the steam engine in the industrial sector: 1835-1881.

	No. of machines	Power (HP)	Comments
1835	1	16	1st official mention of steam engine in industry
1852	70	983	79% of HP was concentrated in Lisbon; 7.2% in Porto.
1881	328	7052	Sectoral distribution (no. of machines): 38.4% in textiles 9.1% in tobacco 8.5% in milling 8.8% in other food industries 7.9% in metallurgy

Source: Castro (1978) and Serrão (1980) based on the Industrial Surveys of 1852 and 1881.

After 1835 the diffusion of the steam engine throughout the industrial sector was consistent but at first circumscribed to Lisbon and Porto.The introduction of the steam engine in Porto was later and the diffusion slower than in Lisbon. Some authors argue that it was at this time that the divergence between Lisbon and Porto begun (Cordeiro, 1996). This observation is of course related to the argument of the uneven technical resource distribution of the country. Overall the diffusion of the steam engine was slow. According to not very reliable statistics the diffusion of the steam engine in the industrial sector obeyed the pattern described in Table 15.

Table 16. International comparisons on the rate of diffusion and penetration of the steam engine.

	UK	France		USA		Portugal	
	Horse power	Horse power	a.a.g.r.	Horse power	a.a.g.r.	Horse power	a.a.g.r.
1830		10000					
1835						16	
1838				36000			
1848		60000	10.5%			983	27.4%
1852							
1860				$1.7x10^6$	19.2%		
1862		205000	9.2%				
1870	725000						
1881						1052	7%
1900				$10.7x10^6$	4.7%		

Source: Pollard (1990) and Castro (1978).

a.a.g.r. : average annual growth rate

In international terms Portugal compared in absolute terms in the way described in Table 16. In terms of growth rate there is apparently a very dynamic first period followed by a much slower rate. The discrepancy or differential in weighted terms is described in Table 17. However unreliable the statistics are, they give a clear indication of the state of backwardness of Portuguese industry even quite late into the 19th century.

Table 17. Horsepower per 1000 inhabitants.

	UK	France	Germany	Belgium	Portugal
1840	13	1	0.6	8	0.02
1860	24	5	5	21	0.25
1881					1.49

Source: Pollard (1990), Castro (1978), Mata e Valério (1994).

However, the economy did grow and the diffusion of machinery throughout the industrial units continued. During the second half of the 19th century infrastructure building helped to sustain that growth and to open the country internally. It is during this period that a national market was built up, in contrast with the regional markets that predominated in the country due to poor conditions of the road and transport infrastructure and to pre-liberal social conditions (cf. above). The construction of roads in concrete started in 1849 and the construction of railway lines started in 1853. The railway mileage grew at an annual average rate of 3.3% between 1846 and 1902 and the road mileage grew at an annual average rate of 11.3% between 1850 and 1900 (Castro, 1978 and Serrão, 1980). A wave of diffusion of new machinery apparatus occurred around 1890. Imports of machinery and intermediate goods raised, new industrial sectors came to life, such as cement, extraction and production of industrial oils, fertilisers and iron. Demand from the primary sector and infrastructure development was partly behind the growth of the industrial sector. Foreign investment began to take hold, and to invest side by side with nationals, in the more dynamic industrial sectors, as well as those connected with material infrastructures such as transportation, communications, electricity and financial services. The technology was in many cases provided by the foreign firms, since there was no indigenous capacity able to supply many products related to the electrical or communications infrastructures as well as to transport infrastructures and machinery (such as trains and the accompanying apparatus).

But in spite of the structural changes, the political stability and the policy of differential protection of national industry, growth was not enough even to maintain the pace with the rest of the industrialised countries (Table 18). Given the initial inferior conditions from which Portugal started in the 2nd half of the 19th century and in spite of being an important period of structural change in Portugal, it was also a period of economic divergence with respect to the more industrialised countries and even to those which were taking-off during that period. Thus, Portugal grew but did not grow enough. It would have to wait more than fifty years before it could attain Rostow's kind of take-off stage.

Table 18. International comparisons of growth rates in the 19th century.

			Annual average rate of growth (%)
1815-1914	France	Industrial Growth	2.03
		Physical Product	1.5
		Output per head	1.2
1815-1914	UK	Physical product	2.65
		Output per head	1.3
1859-1913	Germany	Net domestic product	2.6
		Output per head	1.5
1851-1913	Portugal	Industrial Growth	2.46
		Physical product	1.15
		Output per head	1.17

Source: Pollard (1990), Lains (1995) and Mata (1994)

At the end of the first quarter of the twentieth-century, the capitalist structure of the country was still very fragile and immature. The share of industrial activities in total output was small compared with the share of agriculture. At the end of 1930 more than half of the active population was still employed in the primary sector and only one fifth was employed in the industrial sector (less than the share employed in the services sector; see Table 19 and Figure 4). The numbers should be compared with those of the UK, for instance, where in 1801 the share of active population employed in agriculture was 35.9% and in 1851 was 21.7%, or the numbers in Germany, with a share of 54.6% in 1849/58 and 35.1% in 1910/13. Only Japan, a latecomer to industrialisation, showed larger shares in primary employment, namely 73% and 66% in 1887 and 1902 respectively. The technological base of the majority of industrial units was extremely backward, the share of consumer goods in total output was large and capital goods share was extremely small, huge conglomerates similar to those that emerged in other industrial countries were in a embryonic state and the financial sector was underdeveloped, as well as the infrastructure system (roads, railway, communications). The Portuguese economy as a whole was not, at the time, affected by the business cycle phenomena, which is a good indicator of the level of capitalist development of the country.

We recall now the initial arguments that tried to explain this process of development and we shall add some additional comments. Our aim here is to add additional explanatory factors to them and to enrich the corpus of knowledge, although we have made some observations when it was considered appropriate, because any tentative explanation of the development level of the industrial sector and its innovative capacity includes several interacting factors. But we think that there are two factors that were particularly influential.

The first is the state of the educational system and the level of education of the population which acted as a multiplier of the problems of the country, since in so far as its absorptive capacity was extremely low, reduced considerably the alternatives opened to society as a whole. The severe underdevelopment of the educational system, characterised by an enormous illiteracy rate, large deficiencies at the elementary and secondary level, an incipient technical education and an outmoded university education, all adding together to result in an insufficient and backdated human resource base. This is true in spite of the fact that a concern for educational matters was present at official level and there was an awareness that there was a correlation between industrial development and educational level. However these concerns did not express themselves in deeds and the state did not invest in education. Private efforts were present but they were far from providing anything that resembles universal education even at basic level. We shall recall that alongside with this lack of priority in investment in knowledge or intangible capital there was a great deal of investment in physical infrastructure. Thus, one possible explanation for the lack of investment in education is the pressure of the lobbying groups on the government (itself infiltrated by elements of powerful private interests). These lobbying groups may have included foreign groups since a great deal of the public works were contracted to, or benefited, foreign companies. There is also the consideration of a more cynical perspective relating to a deliberated policy of lack of investment in education imposed by the developed nations on Portugal and the resulting improvement of the terms of trade and competitive advantages of those nations arising in a context of competition between countries within a global capitalist system, a theme that takes us back to the theory of dependence of Portugal, which is eloquently defended by some authors (Mhull, 1982). In any case the lack of official priority for education is a mirror of the lack of priority for education sensed by society as a whole or by its most powerful groups, namely the large landowners and the merchants. This leads us to the other argument relating to large interests retained by large landowners in the continuation of semi-feudal production relations (in the primary sector) and concomitant impediments to the modernisation of the country, perpetuating a social structure marked by a relatively high level of rigidity and raising all sorts of obstacles that resulted in a difficult and slow transition from a feudal or semi-feudal mode of production to a capitalist mode of production, goals that were facilitated by the deficient communication infrastructure and the relative isolation or at least difficulty of movements between regions.

This theme is also intrinsically related to the argument of the lack or else an inefficient entrepreneurial spirit or mentality, another argument advanced at the start of the section and which makes an echo of the arguments of the literature on the causes of the underdevelopment of the Portuguese economy and as a possible explanation of the underdevelopment of the industrial sector. The common line of reasoning in the literature is that the typical Portuguese capitalist preferred investment in land and commerce or in state sponsored business to the detriment of industry, an attitude that was dictated or explained more by sociological reasons (social mobility and/or acceptance, fear of progress) than by rational economic behaviour. In a comparative study of the Portuguese textile industry Ingerson (1982) sees no radical differences between the investment portfolio of 18th century British capitalists and 19th century Portuguese capitalists with industrial interests. Fonseca (1987) reaches basically the same conclusions or at least defies the archetype of Portuguese rich bourgeoisie showing that the motivation behind the investment was as rational as it could possibly be, given the circumstances of expected rates of return. Investment in industrial projects was apparently more risky in Portugal than elsewhere (namely in the developed countries) and the profits were not as great as they were elsewhere. According to the argument it was the circumstances that were to blame not the capitalists. This argument is expanded by Reis (1984), who tries to prove, through the use of the so-called “counter-factual methodology” of the “New Economic History” school, that the investment choices made at the time were, perhaps not the best, but at least not very far away from the optimum. He does not however make a similar exercise with the educational factor (which, we may concede, is understandably difficult to make). The argument is somewhat plausible if we take into account the reduced knowledge base of the country, the national scarcity of producers and supply of capital goods, the lack of technical services, the need to import technical and human resources for more ambitious industrial projects, a series of difficulties related to transport and communications and a small internal market compounded by a lack of official protection (asides from import tariffs) such as procurement. However it is also true that the proportion of total investment of Portuguese capitalists made in direct industrial investment was extremely small, and the vast number of small, familiar industrial initiatives was deficient in substantive knowledge, innovative characteristics, manufacturing processes and production organisation. Mónica (1987) says that industrialisation in Portugal benefited greatly from foreign agents, namely important British and French industrialists with established interests in their countries of origin, or more modest technicians that established themselves in Portugal. An important contribution to industrialisation came also from rich Portuguese merchants who made their fortunes in Brazil, and later returned to Portugal. Mónica also subscribes to the argument (similar to Reis) that the initial conditions and the characteristics of the country did not permit the desired industrialisation at the time. It emphasises particularly the weight of the state in the economy and the close links between the more important capitalists and the state and the not always clear actions undertaken by the latter.

The second factor, which in itself is also partly a consequence of underdevelopment (thus creating a vicious circle), probably having a direct cause-effect relationship with the first factor, is an unbalanced industrial structure characterised by the primacy of the production of consumer goods and its huge dependency on foreign capital goods and intermediate goods.

Rosenberg (1977) suggests the fundamental importance of the capital goods sector in the creation of a sustainable indigenous technological capacity and its diffusion throughout the economy. The pattern of user-producer relationships in the process of innovation is also stressed by Lundvall (1988), who argues that close, continuous, strong, effective interactions are paramount in the process of technological innovation, and in defining specialisation patterns within national borders. The absence of these information flows undermines the process of developing indigenous technological capability, as illustrated by Unger (1988) in the following statement:

> "However, the user-producer approach also argues that inertia tends to consolidate the existing user-producer networks, an inertia that leads to decision-making on the basis of past experiences. This inertia develops not only within national systems of innovation, but also with regard to relationships involving domestic user firms and foreign producers well established in the international machinery or technology markets. This is a picture extremely familiar to many LDCs. Thus the permanent links reinforced through imported capital goods and technology create a degree of technological dependence that may not be overcome unless very specific policy measures are targeted to that end." (Unger, 1988, pp.482-483)

And indeed the Portuguese economy did follow this familiar pattern. So, lacking an adequate capital goods sector and facing no demand from the consumer goods sector, the very important ingredients necessary to develop its own technological capability are, from the outset, absent from the Portuguese economy. During the second and third quarters of the twentieth-century, the industrial or development polices were not so much in the promotion and support of domestic capabilities but rather relied on a rather classic pattern followed also by other NICs, a conjugation of tariff protection, price controls, public support and procurement of investment related to infrastructure development, and a policy of supporting the creation of industries with potential import-substitution effects on consumer goods.

5.2 The first quarter of the XX century

The first quarter of the XX century was again a period of considerable turmoil in Portuguese society (from 1910 to 1916 there were 16 governments and from 1920 to 1926 there were 29 governments). In 1910, after the assassination of the King two years earlier, the monarchic regime was replaced by a Republican political regime. The economy suffered a considerable setback (see Annex D), the two most proximate causes being the deplorable state of public finance (the state resorted to public borrowing to finance infrastructure development, particularly railways and roads and it did not managed to control the debt) and the first world war, in which Portugal entered on the allied side.

Table 19. Employment structure in 1890-1925.

	Agriculture	**Industry**	**Services**
1890	61.8%	17.9%	20.4%
1900	62.2%	18.7%	19.1%
1910	57.8%	21.6%	20.5%
1920	56.0%	20.5%	23.4%
1925	55.2%	19.8%	25.0%

Source: Neves (1994).

Note: agriculture includes fisheries.

The 1910s is the only decade since 1850 that has a negative annual average rate of growth (-4.6%). It represents a period of deep economic depression and strong inflationary pressures. In spite of the political turmoil, overall the period is characterised by consolidation and upgrading of technological industrial capacity, although at a slow rate again. It is during this period that the seeds of some of the future large Portuguese conglomerates were planted, as well as the development and growth of the financial system. The industrial conglomerates created some of these financial institutions. New technologies were adopted and diffused through the industrial sector (e.g., electricity), replacing old steam vintages, and infrastructure development in communications continued (although the railway mileage and the road system suffered an investment cutback). Foreign investment was again behind many of the innovations introduced during this period and, in general, the structure of the industry was characterised by a few progressive firms (not necessarily very large and certainly not as large as many contemporary European firms) surrounded by a myriad of small, traditional, slowly developing firms. Changes in the structure of employment developed slowly. Employment in the primary sector diminished only gradually and secondary employment registered almost no change (Table 19 and Figure 4).

What characterises most this period is probably a slow and gradual but “safe” rate of “capacity building” in the sense that there was more preoccupation with technical education (albeit modest) and there was more learning value added in the contact with new technologies brought by or through foreign investment or foreign indirect control.

In 1926 a military coup created the “Estado Novo”, a totalitarian regime that was to last for the next half century (forty-eight years), ending only in 1974. The coup enjoyed popular support due to its pledge for a policy of social and financial stability (the two main social nightmares of the time). The financial crisis (a public debt above 86% of GDP in 1923 and a public deficit above 8% of the GDP) and an inflation rate that eroded the currency were already being tackled before the coup but the new regime got the credit for it (Neves, 1994) and it probably managed the affair more efficiently, or at least created suitable conditions for managing the affair more efficiently.

During the 1930s the regime defined its basic institutional structure by approving in 1933 a new Constitution and by exacting many of its fundamental economic laws. It defined the institutional structure that would be in place during the phase of rapid growth that followed the 2nd World War. It was a structure characterised by a large degree of state control over economic affairs. The interventionist posture of the state was formalised in the planning exercises that characterised the regime. The first long-term development plan, which was a sign of that posture, dates from 1935 (Neves, 1996). It is a fifteen-year programme of public investments, called the Economic Reconstitution Law, whereby defence expenditure absorbed about 50% of total investment and agriculture, transport infrastructure and telecommunications (with 31%, 27% and 9%) reflected the priorities at the time. The new regime maintained the traditional tariff protections and it additionally introduced controls for foreign investment, forbidding foreign direct investment in certain sectors.

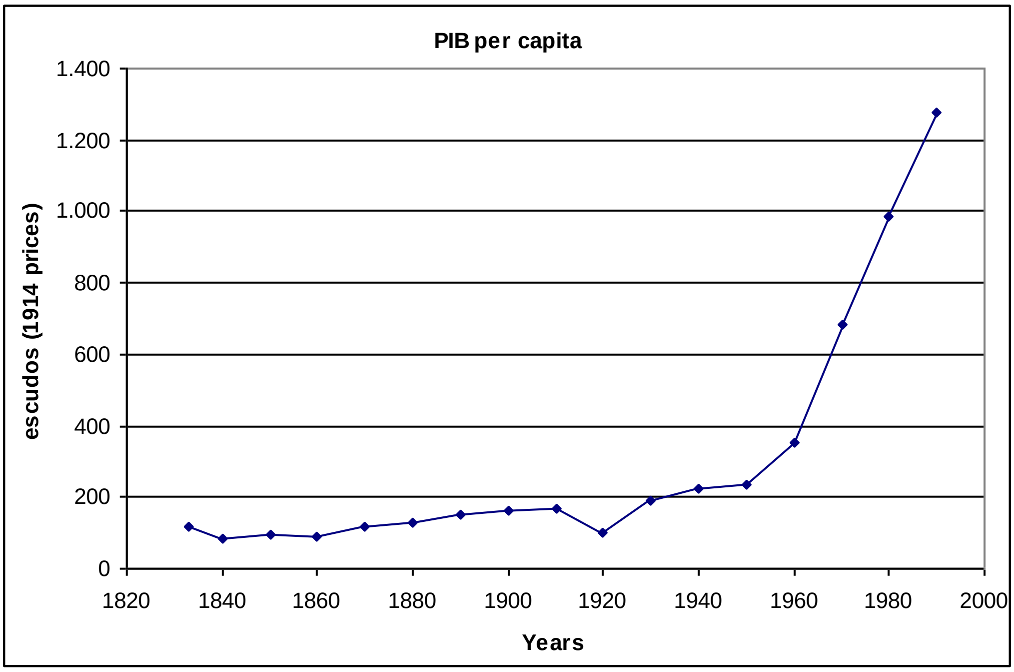
5.3 From 1945 to 1974

It is generally accepted (Guimarães and Martins, 1989, Neves, 1996) that the real industrial take-off for Portugal took place after the Second World War, partly as a consequence of a series of contingent factors, of which:

- Availability of considerable financial resources, obtained by the exploitation of the neutral position of Portugal during the war.
- The cumulative diffusion and strengthening of scientific and technological capabilities and infrastructures.
- The increase in internal consumer demand.
- A post-war general world economic expansion period.
- Accession of Portugal to international organisations (NATO, OECD, and UN) constituted mainly by developed countries whose standards would gradually be absorbed by Portuguese decision-making.

Based on the concept of “equilibrium of poverty” developed by Galbraith (1979) and in similar conceptual approaches, Neves (1991) estimates the break-off point of Portugal of the poverty trap, or in other words, the breakdown of the “equilibrium of poverty", and places it around the final part of the 1920s. Only later was the country in conditions to enter a period of continuous and sustained growth. The take-off is rather well illustrated by the available numbers and by its graphical representation in Figure 2. It is very clear from the picture where the take-off point for Portugal in terms of GDP per capita is situated, namely at the beginning of the 1950s. The trend for above average growth was already visible since the 1920s.

Figure 2. Gross Domestic Product per capita (1914 prices).



Source: Mata e Valério (1994).

Note: The numbers on which this graph is based are tabulated in Annex D.

According to the numbers in Annex D average GDP growth rate during the period 1920-1925 was 7.0% and for the period 1925-1930 it was 8.0% (part of this growth is probably due to a recover from a severe recession in the 1910s). The recession during the period 1940-1945 is explained by the war. The table in Annex D includes particular dates (in the 20th century) that are important because they are landmarks of Portuguese society, signalling important discontinuities, either political and/or economical. They are:

1- 1910: the monarchy is abolished and the political regime becomes republican, with elected parliament and president.
2- 1925: the year before the "coup d'état" that puts in place the "Estado Novo", a dictatorial regime that will last until 1974.
3- 1973: the year before the "coup d'état" that restores a democratic regime.
4- 1985: the year before accession to EEC.

Economic policy at this time was guided by the general principle of macroeconomic stability, through monetary and exchange rate policy within a framework of control of movements of capital, services and goods with other countries, and through a budget policy aimed at the equilibrium of public expense and public revenue at low levels of GDP. At the microeconomic level there were several mechanisms of market regulation through which the private initiative was defined (Confraria, 1995).

The industrial policy during this time, generally known as the "condicionamento industrial" (industrial conditioning), was made operational in a series of medium term plans (the Development Plans). The policy behind them conferred to the government a rather interventionist stance, literally having the last say in any new industrial investment project or on the expansion or contraction of existing ones (prior authorisation for investment was needed). The system is best described as a "state capitalism", essentially different from the liberal forms of capitalism in the sense that, although the investment resources are privately owned, their allocation is strongly dependent on government policies. The general objectives of the policy, corporatist by nature and paternalistic in character, were (Confraria, 1992):

- To avoid the lack of or too much competition
- To avoid the nationalisation of the industry
- To avoid negative effects caused by unequal regional distribution

- To avoid failure caused by the lack of a technological basis and/or financial guarantees and its negative impacts on the working class when its livelihood is dependent on precarious firms

They were based on the belief that the free operation of the market or free competition was a mechanism that would lead to inefficiencies in the allocation of resources, to inefficiencies on the time scale necessary for adjustment and would impose unnecessary and unacceptable social costs. Having in view the comparative disadvantages (namely at the technological level) of national industry and the objective of developing some national industrial capacity, restrictions to foreign investment and differential protection of domestic industry from international competition were imposed.

The policy of “condicionamento industrial” regulated competition through the regulation of investment, as mentioned, trying to co-ordinate the entry decisions of new firms and the expansion decisions of existing firms, as well as accelerating the exit of inefficient firms and favoured investment that would imply import substitution. Competition was also regulated by direct or indirect price control and wage regulation through the corporatist institutions (Confraria, 1992 and 1995).

Analysts of the system (Brito, 1989, Confraria, 1992) concluded that the system had more negative than positive effects, by imposing serious non-market entry barriers, by creating a sort of complicity between the main private conglomerates and government officials resulting in inefficiencies and distortions of all kinds, and by hampering the competitiveness and dynamism of individual units, impeding innovation and R&D strategies.

The Development Plans (applying from 1953 to 1973; see Table 20), emphasised the development of infrastructure, energy and industry. Although little more than lip service was dedicated by the plans to technological research and training (except the last Plan, which realises more strongly than the others the importance of these factors to the economy), the fact that they were included in the plans reveals the increasing importance that technical matters acquire. Support was given to develop the public research laboratories, many of which started after the war, with the proclaimed aim and main function of technically supporting the ongoing development in the specific sectors were they were needed. For instance, in 1944 it was decided that the strategy for energy production would rely heavily on hydroelectric energy. It followed a huge programme of construction of dams (the importance of which is still visible all the Plans) and the LNEC (Laboratório Nacional de Engenharia Civil), one of the largest state research laboratories, was then created to provide technical support to that endeavour.

Table 20. The Development Plans (Planos de Fomento)

	1st Plan (1953-1958)	2nd Plan (1959-1964)	Interim Plan (1965-1967)	3rd Plan (1968-1973)
Total investment (Current prices; 10^9 Esc.):	11.477	27.118	13.13	122.2*
Percentage applied in:				
Agriculture, forestry and fishing	10.8	14.6	9.1	15.1*
Industry	18.5	28.3	38.2	25.2*
Energy	41.2	26.1	20.6	14.7*
Transport and Communications	29.5	38.9	19.0	22.2*
Research and Education	-	2.1	3.0	4.6*
Tourism	-	-	3.1	9.7*
Health	-	-	1.0	1.9*
Housing	-	-	5.8	6.6*

Source: OECD, Economic Surveys of Portugal, several issues, except when signalled with an asterisk where the source is Neves, 1994. The figures are not strictly comparable, since the data presented by Neves refers only to the original intentions of the plan and only investments in continental Portugal and Atlantic Islands but not in the African colonies of Angola and Mozambique.

The Portuguese economy was also characterised in this period by an increasing openness. On the one hand, and in spite of the policy of protection, tariff barriers actually decreased in terms of percentage of total imports (Table 21) because of the commitments of Portugal to the International Organisations that it joined, being no more than 5,6% of total imports in 1975. On the other hand, the share of exports in GDP increased significantly (Table 22 and Figure 3), reaching in 1990 36% of GDP.

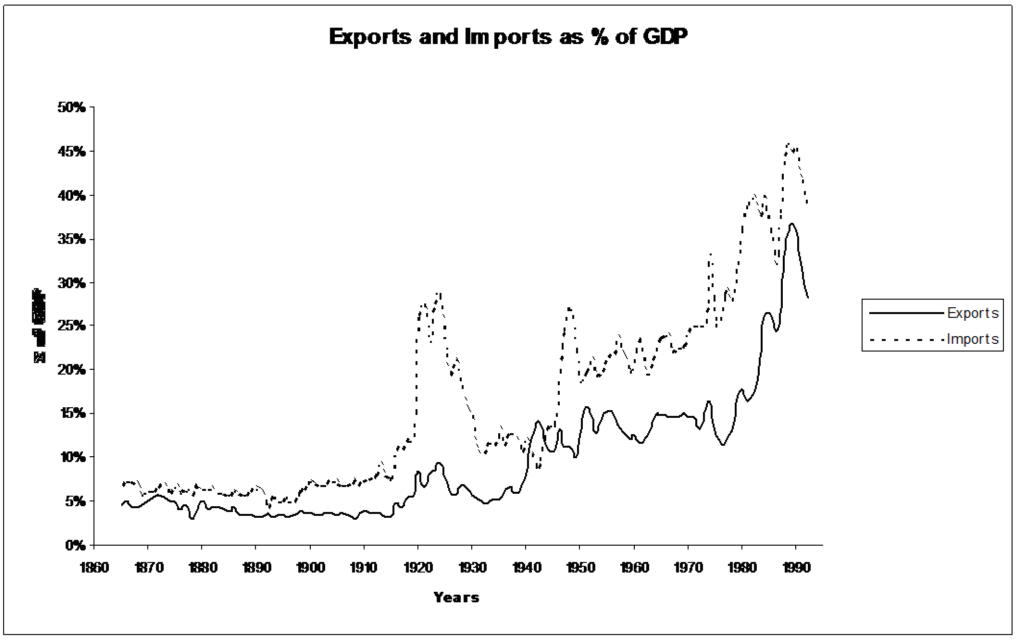
Table 21. Levels of tariff protection: import duties as a percentage of total imports

1930	1940	1950	1960	1970	1975	1980	1985	1990
23.5	19.8	13.5	14.5	10.8	5.6	2.5	1.7	0.6

Source: Mata e Valério, 1994. Note: Confraria (1995) differentiates nominal from effective protection rates. The ones in the table are nominal. The effective rates are generally two to three times higher.

This situation is not different from the general path followed by Europe after the 2nd World War, in particular the deliberate policy followed by the European countries to base their post-war recovery on a policy that relied on wage moderation, large investment and exports (Crafts and Toniolo, 1996).

Figure 3. Exports and imports as percentage of GDP.



Source: Neves (1994).

Although the situation was not comparable to those countries that suffered the worst of the war, Portugal nevertheless adhered to the European and international compromises and institutions set up after the war to secure the mutual commitment of European (or other) countries in open export markets and to co-ordinate those transactions, namely the OEEC (Organisation for European Economic Co-operation), the

European Payments Union, the General Agreement on Tariffs and Trade, the International Monetary Fund, the Marshall Plan, the United Nations and NATO. It was also a founding member of EFTA, the European Free Trade Association (it signed the Stockolm agreement in 1959) and it is within the framework of the agreement with EFTA (which conferred access to new European markets and maintained temporary protection of Portuguese export sectors) that exports began to increase significantly. The accesion of Portugal to EFTA is not only an important economic but also a political landmark marking the more or less definite orientation of Portugal towards integration in the European regional block (Sousa, 1995). The growth of exports becomes even more accentuated after accession to the EEC, and is accompanied by a substantial growth in foreign direct investment.

Table 22. Degree of openness of Portuguese Economy.

	As percentage of GDP (current prices)		
	Exports	Imports	F.D.I.
1940	8.01%	12.07%	
1945	10.71%	13.40%	
1950	12.62%	18.65%	
1960	12.57%	20.97%	
1970	14.70%	24.50%	0.4%
1980	17.73%	36.39%	0.5%
1985	26.54%	36.23%	1.0%
1990	36.12%	45.16%	4.3%
1992	28.42%	38.69%	3.5%

Source: Neves (1994).

Overall, the 1950s, 1960s and earlier 1970's marked a phase of transformation of the Portuguese economy. GDP growth rates (and industry output growth rates) were among the highest in the OECD area during the 1960s (only exceeded by Japan, Spain and Greece) averaging 6.6% per year between 1960 and 1968 and 7.4% between 1968 and 1973 (Table 23).

New sectors came into existence (pharmaceutical, heavy machinery, steel) or were quantitatively and qualitatively improved (electronics, petrol refinery, chemicals, pulp and paper, shipbuilding, electric machinery), traditional sectors lost some of their relative importance, although maintaining an important contribution to GDP with certain sub-sectors developing considerably (such as footwear, or some other foodstuffs). The agriculture sector entered a period of increased decline in terms of GDP share but less so in terms of employment. The service sector enjoyed rapid growth (Table 24 and Figure 4).

Table 23. Selected indicators of economic performance in Portugal since 1960 and international comparisons.

	Average Percentage Changes							
	1960-1968		1968-1973		1973-1979		1979-1990	
	Total OECD	Portugal	Total OECD	Portugal	Total OECD	Portugal	Total OECD	Portugal
Real gross domestic Product (GDP)	5.1	6.6	4.6	7.4	2.7	2.9	2.7	2.9
Real GDP Per capita	3.9	6.3	3.5	7.7	2.1	1.2	2.1	2.3
Real gross fixed capital formation	6.5	6.0	5.8	10.7	1.1	-0.4	3.1	3.3
Real GFCF: Machinery/equipment	7.2	6.3	7.7	12.8	2.7	n.a.	5.3	n.a.

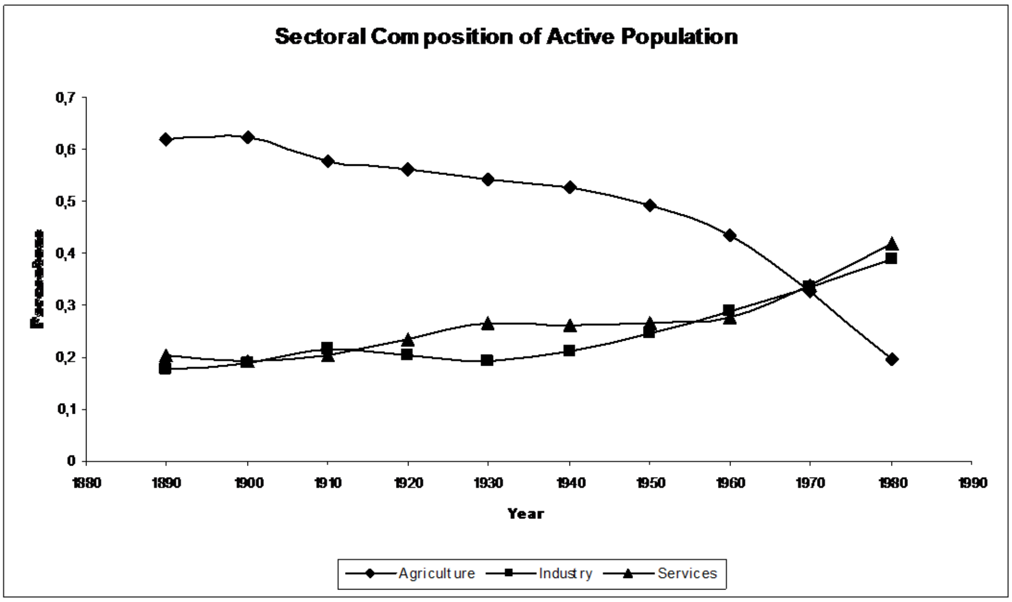
Source: OECD (1992a)

As referred to earlier, the state had an important role in all this process of industrialisation where it participated actively. Besides its role as a promoter of physical infrastructure (energy, roads, railways, etc.) and its procurement function, the state intervened directly in the formation of companies and in specific industrial projects, of which petrol refinery is an earlier pre-war example. Strategic sectors were identified, and the state often took the initiative to build-up the sector in Portugal, in an effort to substitute imports and make the country less dependent on foreign. The market structure was often imposed by the state by the concession of privileged and limited exploration rights. The introduction of petrol refinery in Portugal involved the creation of a firm with mixed equity, i.e., the company was owned by the state and by private entities. Often the private shareholders were foreign firms that possessed the necessary technology or controlled access to resources. In some other cases the private shareholders were the few Portuguese corporations that existed then. Generally, the creation of these mixed firms involved complex agreements, regulating the scope of the firm's activity. The firms could be managed by the private shareholders but this was often conditioned by state direct or indirect intervention. The same pattern was present in other large industrial projects, such as electricity production and distribution, nuclear energy, railways and underground, base chemicals, paper and steel. At the end of the period a handful of large conglomerates with large interests in industry, banking, insurance and agriculture consolidated their position as the main players in the national stage and as the main interlocutors between the state's industrial policy and the market. The installation of industrial capacity in the African territories under Portuguese administration was an initial training ground for future activities related to internationalisation that will come effectively almost a decade later.

On the other hand, state intervention in traditional sectors, such as wood and cork, textiles, equipment and machinery and others, was more of the regulatory type than the sponsor type, notwithstanding, of course, its important procurement programme that indirectly benefited these industrial sectors. The share of machinery/equipment in industrial output increased substantially during the period 1958-1973, which in itself was a positive sign regarding indigenous technological capacity. The development of the sector was partly related to the electrification programme of the country, where electromechanical equipment for electricity production, transformation and distribution was needed, and the programmes related to railway and naval upgrading, where electromechanical equipment and heavy transport equipment was produced. It also enhanced a general expansion of the machine-tools sector and other industrial equipment. Due to the size and demand limitations of the domestic market some firms became more active in exports of parts and components on a sub-contract basis, and also of entire machines. But the main export sectors were still the traditional sectors of textiles and foodstuffs, although there was an upward trend in the export share of machinery and transport equipment (an increase from 3,4% in 1965 to 12,7% in 1974).

Regarding either the new sectors or the traditional ones there was a significant increase in the rate of transfer of technology in industry, by means of the numerous licence agreements implicit in almost every new industrial project and often present in expansion, upgrading or new product development of existing firms. The educational and research sub-systems also improved alongside and contributed to the absorption of knowledge and technology. In fact, the relationships between the sub-systems involve mutual reinforcements, that we shall try to analyse below.

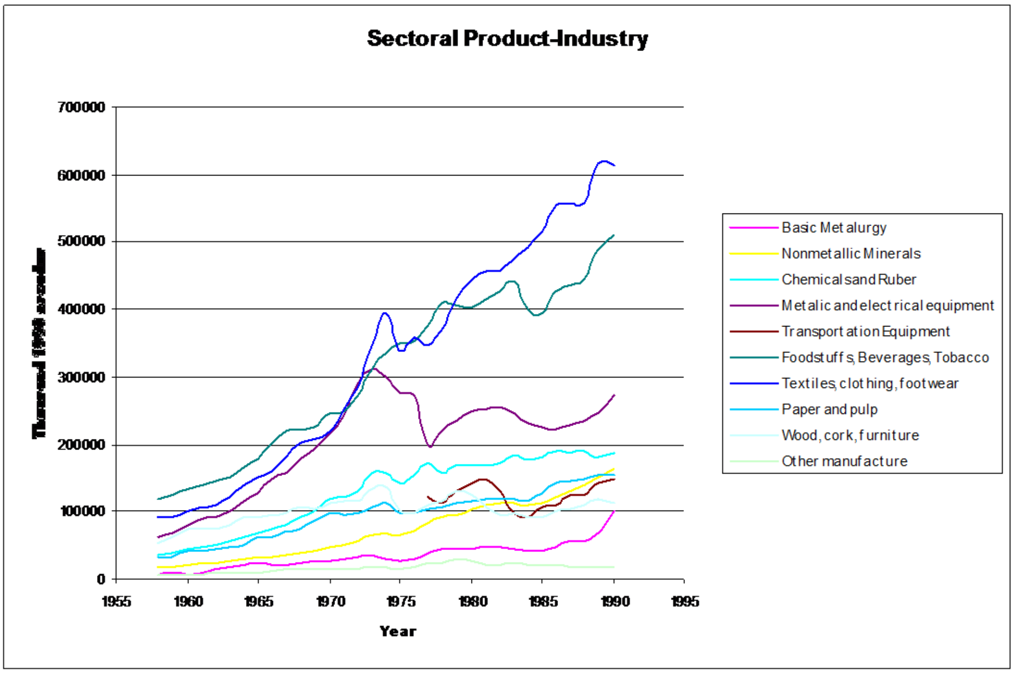
Figure 4. Sectoral composition of active population.



Source: Neves (1994).

Another important development during this period was the concentration process of the banking system in Portugal. This concentration process was partly linked to the growth and increasing power of the few industrial Portuguese conglomerates that entered the financial sector to avoid shortages of credit from the part of the public sector. The banking sector also became more active as an intermediary between private savings and industrial investment, although it still preferred operations not linked to industrial investment because it attached a high risk to those investments. In general, interest rates for credit to industrial investments are higher than to other credit (such as construction or consumption), and credit is given on a short-term basis. A traditional lack of private investment banks or the reluctance to provide credit for industrial investment is a feature that it is still present in today's system.

Figure 5. Sectoral composition of industrial product.



Source: Neves (1994).

Overall, this was a crucial period of development for the Portuguese economic structure. It was a period of marked structural change. It was during these decades that the economic structure acquired the characteristics of an industrially developed country. The share of GDP due to the primary sector decreased from 42% in 1938 to 16,3% in 1973 (Table 24) and the share of industry increased from 20.8% in 1938 to 38,7% in 1973. The share of the service sector also increased to 45% in 1973. Similarly, the share of active population employed in the primary sector was reduced from more than half of the active population in 1938 to 27,2 % in 1980 (still a very large proportion relative to OECD average). The share of active population employed in the secondary sector increased from 20,7% in 1938 to 35% in 1973. Figure 4 shows the long series for the sectoral shares of active population. It is interesting to note that the industrial sector never occupied a prominent position.

Table 24. Variation in sectoral composition of GDP (1977 prices, million escudos) and active population.

	Sectoral product share in GDP			Active Population by sector		
	Agriculture	Industry	Services	Agriculture	Industry	Services
1938	40.7%	20.8%	38.5%	53.0%	20.7%	26.3%
1950	39,0%	23.0%	38.1%	49.1%	24.5%	26.4%
1955	34.6%	23.9%	41.6%	46.3%	26.7%	27.0%
1960	29.8%	27.8%	42.4%	43.5%	28.9%	27.5%
1965	25.1%	32.7%	42.2%	38.1%	31.1%	30.7%
1970	20.3%	36.0%	43.7%	32.7%	33.4%	33.9%
1973	16.3%	38.7%	45.0%	28.5%	35.0%	36.5%
1980	10.3%	40.2%	49.5%	27.2%	36.0%	36.8%
1985	8.0%	39.5%	52.5%	25.4%	34.7%	39.9%
1992	4.9%	34.6%	60.5%	15.2%	32.6%	52.2%

Source: Neves (1994) except for 1980, 1985 and 1992 where the source is OECD, Economic Surveys of Portugal (1996).

Note also that industrial share in total GDP started a downwards trend after 1980. We can say that the bulk of the industrialisation process (in its traditional meaning) was complete by this time. It is also during this period that the industrial specialisation pattern of Portugal takes its shape. According to Confraria (1992) the main sources of industrial employment during the 1960s were the sectors related to transformation of metal but since 1986 the main source of industrial employment were the textile, clothing and footwear industry apparently halting a trend of diversification of industrial product and reverting to the traditional sectors. Structurally, it has remained almost unchanged since then (except for transport equipment, the result of foreign direct investment in recent years, and more specifically since 1980), at least as it refers to the most important sectors, namely textiles, clothing and footwear, foodstuffs, beverages and tobacco and metallic and electric equipment (Table 25 and Figure 5).

Table 25. Variation in composition of manufacturing output (1990 prices).

	Share of sector in Industrial output			Average annual growth rate	
	1958	1973	1990	1958-1973	1973-1990
Basic Metallurgy	1.55%	2.34%	4.39%	11.7%	6.4%
Non-metallic Minerals	4.31%	4.38%	7.16%	8.8%	5.5%
Chemicals and Rubber	8.46%	10.57%	8.17%	10.3%	1.0%
Metallic and Electric Equipment	14.68%	20.96%	11.96%	11.3%	-0.8%
Transportation Equipment	0%	0%	6.54%		0.4%*
Foodstuffs, beverages, tobacco	27.59%	20.97%	22.37%	6.7%	2.9%
Textiles, clothing and Footwear	21.84%	23.41%	27.00%	9.2%	0.0%
Paper and Pulp	7.65%	7.21%	6.74%	8.3%	2.1%
Wood, cork and Furniture	12.76%	8.94%	4.94%	6.2%	-1.0%
Other manufacturing	1.17%	1.22%	0.74%	9.0%	-0.5%
TOTAL	100%	100%	100%	8.7%	2.5%

Source: Neves (1994).

* 1980-1990

5.4 The period after 1974

Since the change of regime in 1974 the economy has undergone major structural changes, falling into three categories (OECD, 1977):

1- Extension of the public sector and, more generally of the role of the state.
2- Changes in the basic principles of the economic system.
3- Decolonisation and its consequences.

After the fall of the "Estado Novo" in 1974 it followed an agitated period that altered significantly the institutional framework of Portuguese society. In the name of the principle of the construction of a socialist society, and following a wave of nationalisation, as of 1977 the public sector controlled 24.4 per cent of total value added and 45.5 per cent of total gross fixed capital formation (OECD, 1976). The degree of nationalisation was more predominant in the utilities sector (electricity, gas and water), the financial service sector (banking, insurance and real estate) and transport and communications, but included also major industrial conglomerates (base chemicals, cement, food processing, steel), precisely, and not coincidentally, those that enjoyed extraordinary growth and support from the state during the previous regime. The dynamics of the private sector was thus subject to a sudden discontinuity with consequences in terms of lack or confused strategies both at internal organisational level and at the level of the market. In addition, the exogenous oil price shocks of 1973 provoked a general deterioration of the terms of trade, enhanced inflationary pressures and altered the expected profitability of earlier investments. A long-term situation of higher levels of public deficit, inflation and deficit in the current balance was initiated.

However, and in spite of the socialist principles pervading the new 1976 Constitution, there were explicit measures taken to stop the growth of the public sector. Yet, and again paradoxically in face of the letter of the Constitution and the institutional changes, there were fundamental changes in the economic principles professed by the state. The most important changes concerning the economic system centred on the private sector and the way it functioned, the labour market and price policies. The government recognised the private sector function of allocation of productive resources and the superior efficiency of the free market mechanism, deviating from its earlier pre-1974 allocation policies that blurred the boundaries between the private and public sector. Wage determination procedures were altered, notably as a result of independent unions replacing the former "guildlike" unions, affecting labour-management relations in a way that resembled more those of the industrialised countries. However, the system of subsidies and price controls remained, to a large extent, in place, raising doubts on whether it helped the enterprises to embark on a more normal operational footing.

The decolonisation process marked the end of the colonial captive markets, an incentive for and an acceleration of the internationalisation process. A formal request for accession to EEC in 1977 and accession to the European Community in 1986 defined the future contours of that often reluctant process. This reluctance was linked to the existence of an alternative strategic perspective for the internationalisation of the Portuguese economy that advocated the creation of an open market whose core geographical boundaries would include all the Portuguese speaking countries, particularly in Africa but also Brazil, but frustrated expectations in the creation of a large and protected consumer market in those countries, the burden of the colonial war and the adverse political context on which the decolonisation was conducted shattered or compromised that perspective. On the other hand, for many economic agents and social segments, European integration was seen as a unique opportunity to have access to a very large although demanding market and a unique opportunity to shake off some of the country's long persisting structural problems. Indeed, the opportunities to increase market share in export markets was quickly embraced as the export numbers relative to GDP and geographical destination show (Table 29) and progress was made in adjustments of the production structure and in improving the functioning of markets.

5.5 Accession to the European Economic Community

The treaty of accession allowed transition periods for some sectors (agriculture, fishing, and textiles, among others) before implementing full removal of all internal barriers. EC membership also allowed Portugal access to Community funds from various sources: structural funds (ERDF, ESF), specific Community funds providing additional aid for certain projects and bank finance including that provided by the European Investment Bank. Those received until now were aimed at improving and upgrading the overall infrastructure system of the country to offset its backwardness relative to the other EC countries, to stimulate human capital formation through improved education and increased occupational training, to give special assistance to the agricultural sector and to raise physical capital formation at all levels, particularly in the manufacturing sector. The process of structural adjustment of Portuguese economy sought to allow for a smooth integration into the Community. There has been a considerable effort to adjust the system in line with the changes that are decided at Community level and one example is the tax system, whereby the former system was replaced by the VAT system.

The attempt to reduce the weight of the public sector in the economy led to the improvement of the financial situation of the public enterprises and deregulation of markets and a process of privatisation that began in 1989, after an amendment of the Constitution allowing for full privatisation of the nationalised companies. Many firms that were nationalised in 1977 returned (totally or partially) to private ownership. In particular almost all financial services were privatised, except the Central Bank (Banco de Portugal) and the Caixa Geral de Depósitos (still the largest bank), the large cement, paper, brewery manufactures, the refineries, the shipyards and even the telecommunications company, just to mention the most important ones. These and other measures have been taken since accession to reduce the accumulated distortions of the economic system and enhance the reliance on market regulatory mechanisms, from which Portugal and Portuguese firms were absent for such a long time due to one form or another of government intervention, in response from the commitments made vis-à-vis the European Union, and more importantly having in mind a not so distant future where all internal barriers will be abolished.

The Community support during the transition phase revived the planning tradition of the Portuguese State. The incentive systems that have been implemented represent the operational side of the economic and industrial policies pursued since. The 1st Framework Programme for Portugal was constituted by four main programmes, two of them directed to sectoral goals and the other two with a more horizontal nature, applied during the period 1989-1993 and representing the main transition period for the Portuguese economy.

The first two were the PEDIP programme (Programa Específico de Desenvolvimento da Indústria Portuguesa-Specific Programme for the Development of

Portuguese Industry) directed to the manufacturing sector and the PEDAP programme (Programa Específico de Desenvolvimento da Agricultura Portuguesa Portuguesa-Specific Programme for the Development of Portuguese Agriculture) directed to the primary sector.

Table 26. The Community Framework Programmes for Portugal.

	1st Framework Programme for Portugal (1989-1993)		2nd Framework Programme for Portugal (1994-1999)	
Total investment: (Current prices: million ECU)	5564		6988 (forecast)	
	Million ECU	Percentage of total	Million ECU	Percentage of total
1. Infrastructures	3258	58.6	4320	61.8
1.1 Transports	1348	24.2	2349	33.6
1.2 Telecommunications	768	13.8	770	11.0
1.3 Energy	689	12.4	519	7.4
1.4 Water/Environment	367	6.6	440	6.3
1.5 Health	86	1.5	242	3.5
2. Human resources	1114	20.0	1173	16.8
2.1 Education	396	7.1	485	6.9
2.2 Training	624	11.2	560	8.0
2.3 Research and Development	94	1.7	128	1.8
3. Production	1005	18.1	1277	18.3
3.1 Agriculture	401	7.2	468	6.7
3.2 Fisheries	0	0	69	1.0
3.3 Industry and services	474	8.5	562	8.0
3.4 Tourism	130	2.3	178	2.5
4. Other	187	3.4	218	3.1

Source: Secretaria de Estado do Plano e Desenvolvimento Regional/Ministério do Planeamento e Administração do Território (1994).

The horizontal programmes were the CIENCIA programme (Criação de Infraestruturas Nacionais de Ciência, Investigação e Desenvolvimento-Creation of National Infrastructure in Science, Research and Development) aimed at developing the research and development capacity of the country and the PRODEP programme

(Programa para o Desenvolvimento Educacional de Portugal-Programme for the Educational Development of Portugal) aimed at the reinforcement of the educational system.

Globally, the combined programmes and investment plan can be grouped according to the categories in Table 26 which allows us to assess the changes in priority relative to the previous development plans and the relative weight/priority of each area of intervention (compare Table 26 with Table 20). Table 26 presents the numbers for the First Framework Programme already terminated and the intentions for the 2nd Framework Programme now in execution. The 1st Framework Programme was less integrated than this presentation leads one to believe. It was more a collection of programmes (of which the main four are mentioned above) than an integrated and well-articulated plan. The same is not true about the 2nd Framework Programme where there was an effort (although not very successful) to integrate the various dimensions of the earlier programmes and to bind them in a coherent way. It is constituted also of major programmes similar to the ones preceding them (the PEDIP is followed by the PEDIP II, the CIENCIA is followed by the PRAXIS XXI, the PRODEP is followed by the PRODEP II, and the PEDAP is followed by the PAMAF).

Relative to the previous “Planos de Fomento” there are significant changes in the perception of priorities. A point in common is the continued importance given to infrastructure development. Infrastructure related to transport and telecommunications consumes a share of 38% of total investment in the 1st Programme and a share of 45% of total investment in the 2nd Programme. Investment priority in transport in the 1st Programme went to the road system (69% of total) which was considerably backward and badly needed upgrading. The first main intercity highways were finally built during this period. The road system remains the priority for the 2nd Programme but additional attention is being given to the railways, namely the upgrading of the lines to permit higher speeds and acquisition of new trains and carriages. Another important aspect, but this time in articulation with Spain and the EU, is the introduction of high-speed trains. On the other hand, energy loses the significance it had in the earlier plans, although Portugal still remains highly dependent on external energy (the motivation for the high investment in the earlier Planos de Fomento). The rate of construction of dams diminished considerably and there was a shift in favour of thermoelectric plants after the (apparently) definite abandonment of the nuclear alternative. An effort to diversify the sources of energy and to rationalise and optimise consumption accompanied this.

The major differences relative to the Planos de Fomento are the shift in the relative position of industry and the productive sectors on the one hand, and education, research and development on the other hand. Industry occupied a prominent position in the Planos de Fomento (reflecting the investments in the major industrial sectors described above and the global industrialisation process that ensued), a position that is now occupied by education, training and research (20,0% and 16.8% of total investment in the 1st and 2nd Programme respectively), for which a minor position was given in the Planos de Fomento (a maximum of 4.6% of total investment in the 3rd Plan). Attention was also given to the direct relationships between technology and industry and a series of projects of an infrastructural nature were supported, namely the implementation of sectoral technological centres (with strong linkages to the sectoral employers associations), technological institutes (with strong linkages to the universities), technology parks and incubators of technology-based firms.

These changes represent a major change in perception of the role and impact of technology in the society and in the economy, and they represents also a change in the perception of how the government should intervene in the economic system relative to the period of the Development Plans. These changes come in line with what was said about the new principles guiding the economic policy of recent governments, namely, to diminish the direct intervention of the government in the economy and let the free market be the main mechanism of allocation of resources and reserving for the government the regulatory role (and the general supervision of the law). Direct government intervention will be restricted to those situations were there is a perceived or potential market failure.

Infrastructure development seems to have contributed substantially to the dynamism of the economy after 1986/1987 and until the first years of the 1990s when the recession began. The period from 1986 to 1990 (Table 27) was marked by relatively high rates of growth, higher than EU average.

Table 27. Indicators of development after 1986.

	GDP 1990p	GDP p.capita	Industrial Production	GFCF	Exports
Percentage changes:					
1986			7.3	10.9	6.8
1987	5.5	5.1	4.3	16.8	10.6
1988	5.8	5.6	3.9	11.2	7.9
1989	5.7	5.5	6.8	4.3	13.3
1990	4.3	4.1	9.1	6.8	10.5
1991	2.1	2.4	0	2.4	0.5
1992	1.1	5.9	-2.6	5.4	6.1
1993	-1.2	-1.2	-2.4	-4.8	-5.1
1994	0.8	-4.8	-0.1	3.9	10.7
Average 1986/1994:	3.0	2.8	2.9	6.3	6.8

Source: OECD (1996d).

The average GDP growth rates from 1974 to 1985 and from 1986 to 1994 (Table 23 and Table 27) were, nevertheless, considerably less than the previous decades (marked by higher extraordinary growth), and probably some of the reasons are to be found in the extraordinary circumstances that followed 1974 and mentioned above (for the period 1974-1985). However in face of the potential for growth due to catching-up, the growth rates for the post-1973 period are deceptive in spite of their EU above-average order of magnitude (but not significantly above OECD average), and even more so when they are compared (as they are often) with the growth rates of countries in similar catching-up conditions, namely the Asian NICs (Table 28). Apparently, the reason is not lack of investment since the statistics of investment in fixed capital show high values close to 25% of GDP for the period 1952-1974, close to 30% of GDP during the period 1975-1980 and again close to 25% of GDP in the 1990s (Neves, 1994). One of the possible reasons is the close linkage of the Portuguese economy with Europe, a relatively slow growth region.

Table 28. Average annual GDP growth rates for selected newly industrialised Asian countries.

	1960-1970	1971-1980	1981-1990
South Korea	8.5	8.7	9.2
Taiwan	9.2	9.7	8.0
Singapore	8.8	9.0	6.9
Hong-Kong	10.0	9.5	8.9

Source: Chowdhury, A. and Islam, I. (1993).

The close links of Portugal with Europe are visible in the increasing importance of Europe as a destination of Portuguese exports (Table 29) and as the origin of Portuguese imports, particularly after 1980.

Table 29. Trade with Europe.

	Percentage of total	
	Exports	Imports
1967[a]	38.1	47.2
1974[b]	39.8	40.0
1980	58.6	45.3
1985	62.5	45.9
1990	73.9	69.2
1995	80.1	73.9

Source: OECD (1976, 1980, 1989, and 1996d).

Note: Europe means the members of the European Economic Community or European Union.

a) UK, Germany, France, Italy, Netherlands, Belgium and Luxembourg.

b) UK, Germany, France and Italy.

Other reasons must be looked for at other levels and particularly at the level of national allocation decision, regarding the human capital component and the educational and training system, the institutional framework of the country and the interactions between the several social and economic agents, and the private (and public enterprises) investment allocation procedures, especially those regarding innovation and research and development.

The perceived "revealed comparative advantage" has remained largely unchanged since accession (OECD, 1994). There has been a slight movement in favour of resource-intensive industries, reflecting the good performance in exports markets of the sectors linked to forestry, at the expense of labour-intensive industries but both remain at the heart of Portuguese industrial specialisation. Its usual weak points (scale intensive industries, science-based industries and differentiated goods industries) remain virtually unchanged (OECD, 1989 and Neven, 1990; cf. Table 25 and Figure 5).

5.6 The economic system: a summary

The relative slow pace at which the economic conditions of the country evolved determined to a great extent its present conditions. The slow transition from an economic and social regime based on feudal characteristics to a regime characterised by capitalist features, a transition that took place during practically the whole of the 19th century, dictated to a great extent the late coming of Portugal to the industrial revolution and lately its difficulties in keeping pace with technological advances and their impact on the economic system. The characteristics of the regime were behind the income distribution structure that was characterised by an extremely uneven and skewed distribution of wealth. Wealth was concentrated on a relatively small proportion of the population and the vast majority of the population was very poor. The proportion of “investing middle classes” was concentrated in the two main cities and insufficient to sustain widespread investment on industrial activities. Investment resources were channelled either to commercial activities or to the primary sector. A large risk was associated with industrial investment due to qualitative and quantitative deficiencies in the knowledge base of the country. An unbalanced industrial structure characterised by deficiencies in the production of equipment goods was at the same time a consequence of the factors just mentioned and a cause of the perpetuation of the situation. The low priority given to state educational policy did not contribute to enhance diffusion of technological expertise and its application at industrial level. Due to the low level of commitment to industrial activities and the inability to master the strategic implications linked to the dominance of technology, a strategy based on a short term perspective and on the exploitation of other production factors (such as cheap labour) took hold of the Portuguese industrial ethos perpetuating an approach with historic roots on a merchant's view of business.

The omnipresent position of the state in the economic system, typified by the absolute control of monopoly or oligopoly concessions over several industrial (e.g., tobacco) and commercial activities (e.g. trade with India or Brazil) continued, although abated, throughout the 20th century in the form of the corporatist regime that was in place during half of the century. An industrial and economic policy based on a state licensing system proved itself to be a two-edged sword, strongly promoting, on the one hand, the industrial development of the country, but, on the other hand, introducing severe market distortions on the way the system functioned. Structurally, the industrial sector remained unbalanced in terms of the proportion of production of equipment goods and consumer goods. Wealth distribution remained skewed although the middle class grew substantially. Nowadays the state is actively engaged in removing market distortions, either by removing all sorts of protective barriers or by limiting its intervening powers. Nevertheless, the educational, technological and distributive heritage is still very visible. The openness of Portuguese economy was a powerful competitive impetus to the industrial sector but its relative weakness may eventually prevent it from readjusting in a timely manner to the considerable threat posed by formidable external innovative capabilities.

CHAPTER 6. THE EDUCATION SYSTEM

6.1 Introduction

One of the main weak points of the evolution of Portuguese indigenous capacity in technical change is to be found in the education system which, quite simply, failed to provide the necessary quantitative and qualitative inputs of human resources needed to carry out the immense and disparate activities underlying the process of technical change. Historically, Portuguese society has never placed education at a high level of priority (in practical terms), although it has always acknowledged and recognised its severe deficiencies at all levels of education and training. Education was not, for a long time, a priority for Portuguese society, and the will to implement changes and commit resources to that task has often remained only at the stage of declarations of good intentions.

Several causal relationships related to cultural, sociological and economic factors might explain the evolution of the education system. Culturally, Portuguese society was a latecomer in embracing the new science paradigm that emerged out of the waves of rationalist philosophy that started with the Renaissance and continued throughout the next centuries, represented by the works of Copernicus (1473-1543), Galileo (1564-1642), Descartes (1596-1650), Newton (1642-1727) and many others, which ultimately institutionalised the mechanistic paradigm of science (Boas, 1970). Unlike Italy, France or England, in which the legacy of the Aristotelian organic paradigm was increasingly losing its regulatory power over science and technology, Portugal remained firmly within the limits of the old paradigm and it did not embrace the new philosophy. On the contrary, it resisted its implementation, preferring to continue along the way paved out by the organic Aristotelian paradigm of science that contributed so much to its world power status in the fifteenth and sixteenth century (Barreto, 1991). The influence of Catholic ideology on Portuguese cultural ethos is not unrelated with the rejection of the mechanistic paradigm whose implicit approach, emphasising analytical fragmentation and specialisation, was at odds with the global, synthetically united view of the Aristotelian paradigm accepted by the church. As a result, the pluralistic view of science which emerged in other European countries during this time did not have any significant reflection in Portuguese society. The existing institutions and their philosophy remained intact and repressive towards the new paradigm. The perpetuation of the old paradigm had of course immense impacts in terms of the educational approach followed by Portugal. Scientific disciplines were for a long time absent from the university (or other) curricula or were inappropriately and deficiently taught.

The social structure of Portuguese society remained stubbornly feudal in character until well into the nineteenth-century (and probably well into the 20th century, particularly in the rural villages), encompassed within a rigid social class divide with little mobility and dominated by patronage relationships:

> "Portugal never experienced the Protestant Reformation; indeed it repudiated Protestantism and took vigorous steps to root it out. Retaining its intensely Catholic culture and identity, Portugal was thus never challenged by the pluralism of beliefs and value systems to which the Reformation helped give rise nor did the this-worldly concerns that linked Protestantism to the growth of capitalism gain widespread acceptance. In part because its industrialisation was postponed, Portugal's middle class grew but slowly, and society remained fixed in the two class pattern of lord and vassal, patron and client, elite and mass" (Wiarda, 1977, pp.40)

As a result, education was a restricted privilege confined to the elite and the church, the vast majority of the population being excluded from even the most elementary education. It can probably be said that the same was true for other European countries but in Portugal the education reserved for the elite was rigid and dogmatic for a long time and lacked the pluralism that emerged in Europe after the Enlightenment. Education at higher levels was monopolistic in character for a long time, repressing the free circulation of ideas and resisting implementation of new projects and creating barriers to proliferation of higher education institutions. The upper classes and the church resisted widespread education of the population well into the twentieth-century (in 1938, during the proceedings of the 1st Congress of the National Union, the most important corporative political and ideological institution under the ruling of Salazar's dictatorship, the glorification of illiteracy is professed by several of its members; see Carvalho, 1986)

The statement of Wiarda helps to complement the system of causal relationships that tentatively explain the evolution of the education system by including the economic dimension. The postponement of the industrial revolution and the continuation of a predominantly rural mode of production contributes to the explanation of low education levels (in rural societies, the fundamental unit of production is the family; the children have an economic function to perform which, in many senses, and even more if it is a poor community, is incompatible with family resources being allocated to formal education programmes).

Table 30. Illiteracy rates.

Year	Illiteracy rates % of total population
1878	82.4
1890	79.2
1900	78.6
1911	75.1
1930	67.8
1940	59.4

Source: Carvalho (1986).

The rate of illiteracy of Portuguese society remained extremely high for a long time (Table 30) either if comparisons are made between the more advanced European countries (rates of illiteracy in Sweden, Germany, England, Norway and Denmark did not exceed 1% as early as 1881) or between the Mediterranean countries or the eastern European countries.

6.2 The background

A factor that contributed to the perpetuation of the influence of the Aristotelian paradigm in Portugal was the influence of a particular order of friars, namely the so-called Society of Jesus, founded by Ignatius of Loyola in 1540 (with the blessings of the Roman Catholic Church). In 1541 the Society established itself in Portugal and since its beginnings it was very well accepted and supported by the monarch and the state. The influence of the order expanded rapidly and it was not long before it controlled an important part of the educational system in Portugal.

There are positive and negative aspects related to the works of the Society in Portugal. The positive aspect is that they provided access to education to a relatively large part of the Portuguese society, i.e., they institutionalised public (open to all classes) education at every level (primary, secondary and tertiary). Thanks to the Society education, particularly primary, was much more widespread than it otherwise would have been, and at a relatively low cost for the state. This is one possible reason why the order was so well accepted and supported by the monarch and the state. Another reason is that it helped to unify and to preserve the unity of the Nation.

The educational system of the Society was very well organised and systematised. Education was divided in three learning cycles, which can be roughly compared to the actual primary, secondary and tertiary level. They founded the second university in Portugal, in a town called Évora (the University of Évora, founded in 1559), almost three hundred years after the first one was founded (see below) and during the two centuries that it lasted it was the only alternative to the other university (the University of Coimbra[1]; see below). The education was of a scholastic nature and it was based on

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[1] The first University of Portugal was set-up in Lisbon in 1290 under the name Estudo Geral but it was transferred to Coimbra in 1308. Subsequently it was again transferred to Lisbon and it was only after a number of such transfers that the university settled in

the exegesis of Aristotle texts and thinking. The order soon organised a number of manuals, completed during the 16th century, that were adopted as standard textbooks throughout all their schools (and apparently also adopted in many other schools in the rest of Europe), and adopted the pedagogical methods used in the University of Paris at the start of the 16th century.

The negative aspects are essentially connected with the excessive duration of the influence of the order in the education system in Portugal and its inflexibility and lack of pluralism of ideas. The order controlled public primary and secondary education for approximately two centuries (until 1759) and its methods and educational contents remained virtually unchanged during that extended period of time. At the tertiary level the situation was characterised by a duopoly. On one side the University of Coimbra and on the other the University of Évora, but their philosophical orientation was not significantly different (both followed the Aristotelian philosophy). Teaching of sciences was oriented towards a moral and religious end, i.e. it was a means and not an end in itself, whereby the sciences were subordinated to Theology. This approach, together with the influence of the order at national level constitute the main target of criticism of the Society of Jesus, namely that it erected barriers to the historical process represented by the Renaissance.

The pluralistic mood towards science that emerged in Europe did not find its way to Portugal. The existing institutions, of which the University of Coimbra plays a crucial role, remained attached to the old philosophy and repressive (at a minimum impermeable) towards the new one. The first Portuguese University, the University of Coimbra, set up in 1290, remained the sole one (with the exception of the interim period of two centuries, from 1559 to 1759, during which the University of Évora was functioning) until 1911, exerting a virtual monopoly power. It strongly opposed (or raised difficulties to) the introduction of the new disciplines arising from the scientific revolution then taking place in Europe.

Coimbra in 1537. It is generally accepted that until this date the development of the University was slow, its staff diminutive and its cultural production irrelevant. Its main function was to prepare (reasonably well) staff to supply the state and the church in competition with the monasteries and the synagogues.

The diffusion of new ideas was made through restricted channels. The most common ones were the institution of small Academies founded by aristocrats that promoted conferences and seminars with invited foreign distinguished individuals. It became fashion among the upper class to sponsor conferences and debates about astronomy and the works of Newton or other authors. Some of them installed small private laboratories in their homes. These initiatives seem to have become more common during and after the 1st half of the 18th century. Private tutors hired by the upper classes were another channel of diffusion of those ideas, as well as the incursions of foreign popularizing agents of the new amazing things science was achieving.

Another source of diffusion of modern ideas came from dispersed contributions of Portuguese intellectuals resident in Europe, the so-called “estrangeirados”, who, for several reasons, wrote books intended to propagate new ideas targeted to the Portuguese audience, or critical essays about the state of things in Portugal. The most famous of them is Verney (1949) whose work[2] had an immense impact in Portugal. He was a herald of the pedagogical ideas of the time. It is important to note that Verney makes reference to the state of illiteracy of Portugal in the 1740s, which according to him was already serious by comparison with other European countries. Similar individual contributions came from intellectuals, not linked to any religious order, that studied abroad and returned to the country.

The most important challenge faced by the Society of Jesus in the 1st half of the 18th century was another religious order (the Congregation of the Oratory of Saint Philip Neri, founded in Rome in 1575 and comprising independent communities of secular priests under obedience but without vows) that was established in Portugal in 1659. Initially oriented to the apostolate, later in the mid 1700s defied the teaching monopoly of the Jesuits and obtained from the state similar privileges and support the Jesuits had, initiating also public teaching at primary and secondary level, setting up their own libraries and publishing their own manuals. The Oratorians were much more open-minded than the Jesuits but their basic premises still derived from Aristotelian thinking. However they

[2] See reference; the translation of the title is “The True Method of Studying”.

were enthusiastic of modern physics and chemistry and their teachings included an important study component of practical work. Generally they tried to conciliate Aristotelian thought with the new philosophical waves or to reinterpret Aristotelian thought in the light of the questions raised by cartesianism, rationalism or empiricism, instead of more or less categorically rejecting them like the Jesuits did.

The final blow to the influence of the Jesuits came by reasons not directly connected to reactions to their educational methods and in a radical way when the so-called Marquis de Pombal gained power in 1750. The Marquis was the right arm of the new King (D. José I) and soon ruled the country with an iron fist that was to bring convulsion to some established social interests, one of which was the Society of Jesus (the other target was the most powerful elements of the aristocracy). By then the influence of the Society had expanded to the overseas territories of South-America (Brazil, Paraguay and other countries) where the Society (Spanish Jesuits) by virtue of its apostolate and educational mission had acquired great spiritual but also territorial and administrative influence. They ruled over an enormous territory, dominating thousands of natives and exacting laws that regulated every aspect of a society. Following a treaty of Portugal with Spain, part of that territory, now under Spanish domination, would pass to Portuguese sovereignty. The Society did not accept that sovereignty; it militarily organised the natives and a war followed. This was the start of the end of the Society of Jesus in Portugal. After defeating the Spanish Jesuits, the Society was completely expelled from Portugal in 1759 and all its belongings confiscated.

That action left the educational system in extreme disarray because the Jesuits controlled almost all of it. However there was no immediate attention given to this state of things and the remedy came late and the measures to correct the problem were intermittent. One of the reasons why the process was lengthy is the lack of alternative resources in the country (namely teachers). Another was a relative indifference of the state particularly with regard to the primary and secondary level.

However, it is generally agreed that the rule of the Marquis of Pombal marks a period of transition in the educational system of Portugal (Gomes et al, 1988) connected to the secularization impulse given by the regime. The personality and the actions of the Marquis are complex and contradictory. He generally embraced the ideas of the Enlightenment and he was enthusiastic about the ideas passing through the Europe of the time but on the other hand he was a despot and imposed a repressive and brutal regime that suffocated any pluralism of ideas. The reforms began with the establishment for the first time of a central structure to co-ordinate all questions related to education at the primary and secondary level, equivalent to a Directorate-General[3]. Although we can think of these as a measure aimed at increasing the efficiency of the system it is also true that one of its main functions was to make sure that the schools and teachers abided by the same state-imposed normalised opinions, in the Jesuit style (only the contents were now different).

One of the praised actions attributed to the Marquis was the secularisation of the education and the contribution to the elimination of scholasticism in the educational system. However, only the Society of Jesus was banned from the educational system, which remained to a large extent in the hands of or under direct or indirect control of the Catholic Church, through the influence of other orders (one of which was the mentioned Congregation of the Oratory, more close to the modern ideas of the Marquis and which was influential in the reforms).

Apparently there was an effort to increase the prestige of the primary and secondary teachers by giving them special privileges generally reserved for the nobles. There was also an attempt to fill the national vacuum in teaching skills and resources with foreign teachers but with very limited success (the reluctance of foreign teachers to come to Portugal is probably linked to the highly repressive nature of the regime and its obsessive censorship activity; it may also be due to the lack of physical resources and the unattractiveness of the function in intellectual terms, if not in pecuniary terms; the only foreigners for which it was easy to find candidates were in the military profession).

The most important and durable change was the definition for the first time in Portugal of a global educational policy. The fundamental idea was that cultural instruction

[3] It is a measure in line with a constant centralisation tendency that characterised the

should be administered according to the social function that each individual will perform. The reform demarcated a dualism. There were those who were to be occupied in agriculture or industry that needed no formal instruction at all and the spiritual instruction by the local parish was sufficient. There were others that would occupy high functions and were divided into two categories: those that would need only to read, to write and to learn elementary arithmetic, and those that should proceed to higher studies at university level. For the latter group it constituted the secondary level of education. In short, under this conception, there was created a rudimentary primary level for the "middle-class", an university level for the elite, and a volatile secondary level whose fundamental function was to prepare the individual to the tertiary level. The vast mass of the population would remain with no instruction at all. This configuration would last well until the 20th century. Besides that, and in line with an elitist perspective of society there was also created a special College for the Nobles, in line also with what happened in other European countries where the aristocracy realised that it could no longer live on privileges alone and needed something else to survive[4]. Worthy of mention also is the creation of a professional commercial school, probably the first of its kind in Portugal. It came about as a response to a need to prepare adequately the merchants for their trade with other nations.

In the light of the basic educational policy, it is evident that the more important reforms of the Marquis were in the University and they were characterised by the principles of the enlightenment, rationalism and utilitarianism (Providência, 1997). Besides closing the University of Évora (it was a natural consequence of the expulsion of the Society of Jesus) the University of Coimbra was profoundly reformed (at least those were the intentions). The methods and the contents were subject to a thoughtful and lengthy appreciation, for which a special committee was created. The most remarkable part of the reforms is the one regarding the scientific disciplines, which were finally implemented in the University. Two new Faculties were created: the Faculty of

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regime during the ruling of the Marquis.

Mathematics and the Faculty of Philosophy (equivalent to our modern Faculty of Sciences). It gave special emphasis and financial support to those disciplines that involved experimental work. New monumental buildings were erected, laboratories with state-of-the-art equipment were set-up for physics and chemistry, the School Hospital and other technical support units were set-up side by side with the Faculty of Medicine and an Astronomic Observatory was built for the Faculty of Mathematics. Everything was done with great apparatus and pomposity. It also reformed some of the old faculties and the other remaining Faculties, namely the Faculty of Law, whereby the Roman and the Canonical Law was abolished. However, in practical terms, it was difficult to implement the letter of the reform. As was mentioned it was difficult to find teachers for the new disciplines, and the old teachers regained much of the old power and influence, soon after the political fall of the Marquis in 1777. However, it is generally agreed that the reforms gave a new and definite modern impulse to the university (Ricon-Ferraz, 1993). Comparing the educational system of the Marquis with that of the Jesuits we can say that the system lost in audience but it gained in updating.

The following regime did not gave any continuity to the reform of the university, but the latter had been so far reaching that it made impossible a complete return to the old status quo. It strengthened the literary part of higher education and it restricted even more access to the tertiary level, while at the same time it enlarged primary education and returned it as much as possible to the hands of the church. It thus represented a setback relative to the intentions of the Marquis.

Once again it is at the margins of the main civil educational system that acceptance, diffusion and enthusiasm about new ideologies and the advances in science and technology is realised (Peixoto, 1997). The Academy of Sciences (of a civil nature) was founded in 1780 and it represented the first durable institutional framework of its kind encompassing all fields of science. It was founded by two “estrangeirados” (i.e., two men who spent most of their time in foreign countries, namely the United Kingdom; both were

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[4] The fight of the Marquis with the Aristocracy was an attempt to curtail the privileges of the aristocracy and to create a “new aristocracy” less reliant on privileges and more on economic activity.

members of the London Royal Society). One of the main goals of the Academy was educational, in which respect it differed from similar European institutions (understandable in the light of the poor conditions of available scientific education at the time), besides the usual goal of promoting the advancement of science and its application to the creation of wealth (the connection between science, technology and economy was not yet generally accepted in Portuguese society). The Academy contributed significantly to promote the application of science and technology to all possible fields of activity during the following 19th century, filling to a certain extent the emptiness of the national panorama related to science, technology and technical activities. Its most notable contributions, aside from its educational activities, were the publication of scientific journals and their consultant activity, and the implementation of some specific projects (related to health and geology).

Military Academies (mostly at secondary level but also at tertiary level) are also founded in the late 1700s and early 1800s in Lisbon and Porto (the two main cities) all of them linked in one way or another to technical activities. During the first years of the 1800s primary schools for military personnel and respective families, employing the so-called self-tuition method, were established in many barracks, an initiative that was part of a general plan to improve the professionalism of the army (done after the French invasions at the start of the century and implemented by a British officer). Later, due to its success, the schools were opened to the civil population and concerns with teaching standardisation led to the creation of the first school of teachers in 1816 (Ferreira, 1971-1975). At a lower level mentioned should be made of the “Casa Pia” an institution originally devoted to shelter marginal youth but that evolved in the sense of providing these people with technical skills. In some cases it reached high levels of professionalism, skill and knowledge, so much so that it was called the University of the People (Saraiva, 1980). It may be considered the second professional civil Portuguese school, this one a technical school and not only a commercial school.

6.3 The liberal period (from the first fifth of the 19th century to earlier 20th century)

The evolution of the system during the liberal period (1820-1926) of the 19th century and the 20th century until the dictatorship regime in 1926 was marked by a high degree of instability. Reforms of the education system were made at an astonishing rate reflecting the conflicting views of the various political factions that rotationally occupied the government seat. No due time was allowed for reforms to settle down or even to take place, and many of them were not implemented, being superseded by a new reform. A general sense of instability and disarray pervaded the institutions and the educational agents, seriously affecting the overall functioning of the system. It is a period characterised more by words and declarations of intentions than by deeds, i.e., the laws were unrealistic and inapplicable to the Portuguese situation. Qualitative changes were introduced but its practical implementation was slow and quantitatively limited. Their limited success was due to the economic limitations of the nation but also to internal social resistance to change expressed by the deeply rooted class dualism. Basically the reforms reflected the struggle between the conflicting views of a classical, humanistic paradigm having ancient and strong roots in Portugal as we have seen in the preceding section, and the mechanistic, rationalist and utilitarian view of science and technology espoused by the more progressive elements of society or those linked to industrial sectors of activity (which was not great, as mentioned in the section covering the evolution of the economic system in Portugal). The social forces espousing the latter eventually became dominant after the fall of the monarchy in 1910, and that change in the balance of power is symbolised by the creation of two new universities in 1911 that finally and definitely ended the monopoly of the University of Coimbra and were the culmination of a long process and struggle to inject new and modern perspectives on the education system.

The more important principles governing the changes in the system, during the liberal period, are (Carvalho, 1986):

- the principle of freedom of expression
- the principle of education as a fundamental human right
- the utilitarian perspective of education and training in addition to its socialising function

One of the first measures of the liberal regimes was to abolish the Inquisition Court still operative in Portugal in 1820 (the permanence of such an institution reveals well the level of censorship and restrictions imposed on Portuguese society at the intellectual level). Another measure was to open to anyone the possibility to teach or to create schools (as referred to earlier, the prerogative for teaching activities was restricted and disputed between established institutions linked to the Church, in spite of the attempts by the Marquis to do otherwise). These measures suffered an immediate setback in 1823 when the radical conservative regained power and re-established the old prerogatives for the religious order (moreover, the Society of Jesus was again allowed legal rights in Portugal in 1832, although they never regained their old power). The number of primary schools (which was by then around 1000 for a total population of approximately 3.7 million) was drastically reduced and a general wave of violent repression followed. Soon thereafter the country entered a long period of civil war from which it only emerges in 1834, with the victory of the liberal (democratic) forces (cf. Table 13).

The agitation did not end here because the liberal factions (the conservative and the progressive) continued to fight among themselves. The evolution of the educational system reflected this struggle between liberals, although some basic principles are common to both sides (such as the principle of universal education). Even so, there was a strong tendency from the conservative faction to maintain a rigid hierarchical social class structure and to favour a system based on classic and literary studies, at the expense of the exact and natural sciences that were regarded as speculative and useless. The argument behind the lack of utility of scientific and technical education was that demand for scientific or technical skills by society as a whole was diminutive and thus did not justify priority investments in those disciplines. The counter argument was that the underdevelopment of the industry or the productive sectors in general was precisely due to the lack of adequate national technical skills and that the previous reasoning, if applied in practice, was conducive to a vicious circle.

Anyway, the fundamental laws that would alter the national panorama in terms of public education date from 1835-1844. At the primary level, mandatory education became law (but with no practical consequences). The most important changes were at the secondary level. In light of the principle of freedom of expression the possibility to run private secondary schools was open to every one (and not only to restricted institutions as before). We shall recall that by then secondary education was almost non-existent. It served only as a preparatory step to the university and it covered only a very small proportion of the population usually from the upper classes. The liberal reforms addressed this situation, in the light of the utilitarian principle of education. Their intention was to provide education and instruction that could fulfil the purpose of providing practical knowledge and skills to apply at a professional level. The idea was to create an educational level that could accommodate those that did not want university education but were also insufficiently served by the primary level (which was extremely elementary). With this principle in mind the reforms contemplated the creation of “liceus” (inspired by the French lycée), secondary schools designed for those who wanted a solid secondary level education useful for their professional lives. The schools were effectively created between 1840 and 1851 but they faced enormous difficulty due to the lack of adequately prepared teachers, manuals and equipment. Subsequently the contents of the secondary level were altered several times, either reflecting a greater emphasis on scientific and technical disciplines or reflecting a greater emphasis on classic and literary studies (with a tendency to degenerate into the type of preparatory studies they were supposed not to be). They became effective only at the end of the third quarter of the century, when they were the objects of greater demand from a growing middle class. At the tertiary level, the University of Coimbra remained almost an “untouchable” institution and there is evidence that opposition to some reforms (namely those that threatened its monopoly) came from the university (Cunha, 1937). However, Cruzeiro (1994) argues that the situation post-1820 was qualitatively different from the situation pre-1820. Before, criticism of the University came from inside the university and external criticism was not accepted. Afterwards, criticism came essentially from outside and the confrontation became more acute and nasty (criticism from inside became also more violent). One of the first measures of the liberals was to lower the political level at which the University had to answer, which before 1820 was the highest possible, i.e., the University was directly dependent upon and answerable to the King. After 1820 it was made answerable to the equivalent of a Ministry. There were also attempts to reduce the financial autonomy enjoyed by the University at the time, and in general to reduce its privileges. It seemed that later, instead of a direct confrontational attitude, the strategy followed by the liberals was to develop alternatives to the university by supporting and restructuring existing higher education institutions (namely the Academies linked to military technical support referred above) or to create new ones.

The first higher education schools to challenge the monopoly of the University of Coimbra were founded in 1837, pushed through by strong military interests and by a growing industrial bourgeoisie, against the opposition of the more traditional sectors of society namely the rural, landowner bourgeoisie and the church. The aim was to fill a vacuum, already recognised by earlier governments, related to technical, professional and industrial studies of science and technology. They were the Polytechnic School of Lisbon (Escola Politécnica de Lisboa) and the Polytechnic Academy of Porto (Academia Politécnica do Porto), who formed and trained essentially engineers, in particular civil engineers, industrial engineers and military engineers who would be instrumental during the phase of infrastructure development soon to come. These schools were the successors of the military academies referred to above (Gomes, 1980) founded at the end of the 1700s or early 1800s.

Attempts to implement secondary and medium level institutions for technical and vocational training to support the (mainly handicraft) industrial base were not very fruitful at the start, but succeeded by the mid-1800s, with the creation of the so-called Industrial Institutes (Institutos Industriais) alongside with similar schools covering training in agriculture and commerce. The creation of these institutes at this time is related to the acceleration of infrastructure development and industrial modernisation that pervaded the country in the second half of the 19th century and its purpose was to increase the supply of adequate technical skills and to provide for the needs and the works of the time. The initiative to implement the institutes came from the governmental department that oversaw matters related to industrial and commercial activities.

Other higher institutions created at the margins of the University of Coimbra were the schools of surgery and medicine in Lisbon and Porto, created in 1825 and reformulated and expanded to include a new school of pharmacy in Lisbon in 1835 (Ricon-Ferraz, 1993).

Other Institutions performing what we call today “other scientific and technical activities” (museums, libraries, botanical gardens, observatories, etc.) flourished considerably (at least compared with the existing infrastructure) during the second half of the XIX century (Silva, 1991), many of them sponsored by private entities, namely industrialists.

The utilitarian perspective of education slowly secured a growing number of adepts and other similar schools were set-up until the end of the century, particularly in the 2nd half of the century, many of them by private or charitable entities. This process was stimulated by the growing industrial activity (albeit modest compared to other European countries) and the government recognition of the importance of the industrial sector to the economy (the relative underdevelopment of industry was a chronic concern of government officials, and its policy measures were the outcome of a systematic search for compromise between the industrialists on one side, and the interests of powerful landowners to preserve the semi-feudal character of employer-employee relationships and the anti-science ideology of the church, on the other hand).

The institutional infrastructure supporting S&T education was gradually reinforced and the long battle between classicists and rationalists bent decisively towards the latter when, following the overthrow of the monarchy in 1910, the new democratic, anti-church, political class actively supported the creation of new universities, the strengthening of vocational education and technical training, the general reinforcement of curricula emphasis on scientific disciplines at the secondary level and a more whole-hearted commitment to widespread education.

Table 31. Enrolment ratios in earlier 20th century.

		1890	1910	1926
Population		5105000	5937000	6507000
Registered students	Primary			317000
	Secondary	7378	17691	25604
	Tertiary		1262	4117
	Total	7378	18953	346721
Enrolment ratios	Primary			4,87%
	Secondary	0,14%	0,30%	0,39%
	Tertiary		0,02%	0,06%
	Total	0,14%	0,32%	5,33%

Source: Neves (1994) and Carreira (1996).

The monopoly of the University of Coimbra ended at last with the creation of the University of Lisbon and the University of Porto in 1911, which included, at least, Faculties of Sciences, Medicine and Pharmacy (some of the predecessors of the Faculties were the above mentioned Polytechnic Institutes and the Schools of Medicine amongst other Faculties created anew). The Industrial Institutes were also restructured and became higher institutions, training essentially engineers, and other higher education schools were created in other disciplinary areas, finally diversifying the higher education panorama in Portugal and subsequently contributing to the diversification of intellectual perspectives.

In spite of the proclaimed efforts of the republicans to devote special attention to the eternal problem of national illiteracy, the gap separating Portugal from developed European countries at the end of the 1920s was still considerable, most notably in terms of illiteracy rates (see Table 30 and Table 31) and of the level of overall educational resources per capita (the number of schools was extremely small and those that existed were deficient in many aspects).

6.4 The initial period of the corporatist regime

The corporatist dictatorial regime that was established in 1926 lasted 48 years (until 1974) and many things happened in the education system. We can roughly distinguish two periods: from 1926 to 1960 and from 1960 to 1974.

The first period was characterised by a change in the way education should fulfil its function. The socialising and indoctrinating function of the educational system was emphasised relative to the training function of the educational system. (Mónica, 1978) argues that the main function of the education system at this time (particularly at the basic levels) was one of social control. It was therefore a regression or a reflection of not distant times when the moral and educational component of the educational system were more important than the training function (that the last seven decades had tried to emphasise). Mónica (1977) describes the dilemma the regime faced when confronting the perennial problem of the illiteracy rate in Portugal. For large segments of the conservative forces now in power, illiteracy was in fact a good thing and a situation to preserve in order to avoid political instability derived from the diffusion of revolutionary political ideas extremely menacing to the status quo. The idea was that ignorance and illiteracy was conducive to social stability and docility and the continuation of existing social structures (characterised by the existence of a great duality). These ideas apparently had in one way or another prevailed over Portuguese society. Other segments of the conservative forces, while not disagreeing fundamentally with the necessity to maintain the social structure intact, considered that social stability was easier to maintain if a certain level of carefully oriented education was provided. They also advanced some economic reasons as an argument to enlarge the population recipient of elementary education. The strategy was to condition what they would learn and what they could read and have access to, which was essentially contrary to the principle of liberty of education so dear to the previous liberal regime.

The general negative consequences of this philosophy were, first, the decrease in the duration of the compulsory elementary education to only three years; second, the general degradation of the institutions, courses and requirements for teachers and its expected function; and third, the downgrading of the level of elementary education. This was also apparent at the secondary level, accompanied by a shift of emphasis from scientific and technical disciplines to literary disciplines (coherent with the new socialising function of the education system).

The positive consequence was that the illiteracy rate decreased more rapidly than in any other period for which numbers are known (see Table 30), although at the expense of quality and content. Another positive consequence, this one dictated by the economic needs of the ever-increasing proportion of the industrial sector in the national economy (cf. previous section) was the restructuring, enlargement and general elevation of requirements of professional secondary education. The measure, aside from addressing economic needs related to labour force qualifications, also created a mechanism that contributed to maintain a social divide between the lower classes and the upper classes. The secondary level of the educational system was now divided in two sub-systems. One is the “ensino liceal” or the education provided at the “liceus” and the other is the “ensino técnico” the education provided at the technical secondary schools. The first is, in line of an ancient tradition (cf. above), a preparatory step for the university and as such frequented by the upper strata of society, the other is an end in itself, a place where the fundamental skills of future professional life will be acquired. Cruzeiro e Antunes (1978) argue that in spite of its formal similarity (same duration, same cycle division), the two schools/sub-systems were intrinsically different, corresponding to two social groups with different origins, and those differences are clearly visible by the social profile of the entrants and the respective qualifications at exiting.

In light of the indoctrination and elitist perspective to which the education system was now subject it is with no surprise that the evolution of higher education is characterised by a relative stagnation. The influence of the Church was reaffirmed once again with the signature of an agreement between the Vatican and the state and the Catholic University was established (it had no technological courses). There was no need to increase the size of the higher education system because it was restricted to a small proportion of society. During the fifty long period the dictatorship enjoyed, just one more university was created (in 1930), the Technical University of Lisbon (Universidade Técnica de Lisboa) and it was actually a conflation of several existing higher education institutions (one of which was the above mentioned Lisbon-based former Instituto Industrial, promoted to higher school in the 1910s). The role of the Universities was essentially educational since research activities were potentially threatening to the established doctrine or because they could create a climate characterised by too much freedom of expression, incongruent with the repressive and oppressive political social regime. As such a general climate of political oppression was prevalent amongst the university community, whose already considerable fragility was further upset by widespread discriminatory practices and political persecutions of eminent dissenting intellectuals.

6.5 The final period of the corporatist regime

Following the post-war economic boom and the increasing international mobility of Portuguese society, the needs and the perspective of society begun to change and with it the educational system. A study executed with the technical and financial help of the OECD looking at the educational structure and needs of the educational system (OECD, 1966b) analysed in detail the qualitative and quantitative needs of the Portuguese educational system in the light of expected economic developments. The Development

Plans (see preceding section and Table 20 on that section) include explicitly provisions for education, some of which were based on those studies. Mandatory education was extended to six years in 1964. New audio-visual techniques were experimented with and a Ministerial department was created in 1965 to make studies of the Portuguese educational system (Teles, 1963).

However, at the end of the 1960s the proportion of resources allocated to the national education system was the same as it had been since the early 1950s, at about 8% of the central government budget, and the proportion of this total earmarked to higher education level fell from 22% in 1950 to 12% in 1970 (OECD, 1986a).

The last years of the regime brought about a considerable departure from earlier policies. The new political mood was reflected in the so-called Veiga Simão's Reform (from the name of the Minister of Education that started the implementation of the programme; he was Minister of Education from 1970 to 1974). It was an ambitious political programme, pushed by increasing needs of technical skills from the booming industrial sector and the now considerable openness of Portuguese society, and it unleashed an energetic reaction against the backwards state that the education system had reached, with a view in mind to make the system as universal as possible at all levels and to all the regions of the country and to put it at the service of economic development. Its aims were to definitely implement universal basic education and eradicate once and for all the illiteracy problem, upgrade and enlarge the secondary level and enlarge and re-orient the higher education sector. Pre-primary education was included in the public education system and priority went to the higher education sector. It introduced the principle of permanent education, as a fundamental component of the educational system.

It involved the creation of new primary schools and large numbers of secondary schools, the creation of eleven short-cycle higher education polytechnics (the intention was to be institutionalised later in the 1970s) and four additional universities, three of which were to be outside Lisbon or Porto, in the main industrial districts. It introduced postgraduate courses and degrees, the recognition of postgraduate degrees obtained abroad and new regulations governing the career of university teachers. A major institutional and organisational reshuffling of the Ministry and of its central or regional executive bodies took place, as well as the re-organisation, creation and functional definition of several supporting bodies and agencies dependent on the ministry. Many of these measures were based on the OECD Mediterranean Project (OECD, 1966b) recommendations.

This movement was partly a consequence of educational measures adopted since the late 1950s encouraging postgraduate students to study abroad who for the most part returned home, bringing with them new approaches and perspectives. Government support for education abroad has been a more or less constant policy since the XIX century, but rather discontinuous in character and not supported by a high level of resources. The National Board for Education (Junta de Educação Nacional) set up in 1936 and the Institute for Higher Culture (Instituto de Alta Cultura) set up in 1952 were the main institutional funding bodies of the time. By contrast with the meagerness of resources allocated to the National Board and to the Institute and the irregularity of funding and policies, the NATO fellowships, available since Portugal's accession in the 1950s (1958), were awarded on a very regular basis, following detailed objectives and a well thought out strategy, and they still are, although their relative importance has now declined, and they decisively contributed to the cultural transfer that is embodied in the letter of the reform.

The new universities created under this reform were: the Universidade Nova de Lisboa (as the names says it is located in Lisbon), the Universidade do Minho, located in Braga and Guimarães (serving one of the main industrialised regions of the North of the country), the Universidade de Aveiro, located in the city of Aveiro (serving another important industrial region of the Centre-North of the country) and the Universidade de Évora (serving one of the main cities of the south called Évora). In Annex F the geographical location of each city (and University) can be visualised.

Due account must also be made of the role of the Calouste Gulbenkian Foundation, an organisation sponsored by the fortune of an oil businessman who entered

Portugal in the late 1950s. From its outset the Foundation has supported financially several scientific and technological activities of which fellowships to study abroad are just one. The activity of the foundation has been quite considerable and important, supporting education, research, scientific information and dissemination, and actively seeking to influence education and research policy.

6.6 From 1974 onwards

The decade long instability period following the restoration of democracy in 1974, temporarily delayed (but also added new ingredients to) the educational policy, but on the whole the basic principles just outlined were followed. However, the basic Law that institutionalised the Veiga Simão's reforms, dated from 1973, was never detailed and refined (due to the fall of the regime) and many ad-hoc and unintended events followed, creating a great deal of instability in the system. The new universities were founded (before 1974) and began to take shape, the polytechnic regime was institutionalised in 1979 (but only after the mid 1980s was it materialised in real buildings and teaching activities), and new laws restructured the degrees awarded in high education institutions.

One negative measure, as such often mentioned by industry, was the abolition of secondary level technical education by the new democratic regime (on the grounds that it was an institutional set-up at odds with the egalitarian ideological mood pervading the new regime). Later in the early 1980s the technical education (now under the name of vocational or professional education) was re-established, after the recognition of the negative impacts of its absence, and in 1986 it was considered a priority issue (see below).

Universities were awarded financial, administrative, pedagogical and scientific autonomy in 1983 (a principle contemplated in Veiga Simão's reform). These principles were reinforced by further legislation in 1986 (see below) and in 1988, marking a departing point from the previous heavily centralised feature of the system. Still, some problems persisted, notably that of funding.

Table 32. Number and annual average growth rates of education units in Portugal since 1960.

Academic Year	Grand total	Pre-primary		Primary		Secondary		Tertiary	
		No.	Growth rate	No.	Growth rate	No.	Growth rate	No.	Growth rate
1960-1961	19077	159		18086		751		81	
1965-1966	18928	240	8,6%	17531	-0,6%	1072	7,4%	85	1,0%
1970-1971	19364	317	5,7%	17018	-0,6%	1950	12,7%	79	-1,5%
1975-1976	14615	679	16,5%	11584	-7,4%	2217	2,6%	135	11,3%
1980-1981	15649	1916	23,1%	10575	-1,8%	3010	6,3%	148	1,9%
1985-1986	17121	2547	5,9%	10850	0,5%	3505	3,1%	219	8,2%
1991-1992	19720	5337	13,1%	10543	-0,5%	3607	0,5%	233	1,0%
1993-1994	19586	5388	0,5%	10308	-1,1%	3618	0,2%	272	8,0%

Source: Carreira (1996) and Gabinete de Estudos e Planeamento do Ministério da Educação (1997).

The system has grown substantially since the 1970s, although this trend was visible since the 1960s (see

Table 32). The growth is not uniform for all levels of education. Pre-primary and tertiary levels were the areas with the highest growth rates. The total number of establishements has remained in fact fairly constant due to a negative growth rate in the number of primary units, which has decreased due to demographic reasons (the birth rate has diminished considerably and emigration was also important after the 1960s). Growth was spectacular at the tertiary level, with two growth phases between 1970-1971 and 1975-1976 and between 1980-1981 and 1985-1986.

Eight-year compulsory education was introduced and the illiteracy problem, while still persistent in some social groups, notably the farmers, the elderly and, in general, among the poorer layers of society has improved substantially relative to the past situation. The number of higher education units almost doubled between 1970/71 and 1975/76 (corresponding to the creation of four new universities during this period, i.e., doubling the number of universities, which as we saw above were four by the early 1970s), higher education students doubled between 1971 and 1982, as well as expenditure on higher education which almost tripled between 1971 and 1976 and doubled between 1986 and 1992 (Table 33). The jump in expenditure after 1986 is related to accession of Portugal to the EEC to which we shall refer below.

Table 33. Current expenditure in education.

	Working Expenses	
	Million esc. (1992 p.)	as % of GDP
1961	31800	1,10%
1966	37500	0,97%
1971	75200	1,37%
1976	199600	2,92%
1981	226700	2,67%
1986	264400	2,91%
1991	489400	4,38%
1992	539500	4,76%
1993 [a)]	688511	5.10%

Source: Neves (1994), Carreira (1996) and UNESCO (1997).
a) Current 1993 prices.

Alongside the growth of the public sector, there was an upsurge on the private higher education sector, encouraged and subsidised by the government, a trend related to the inability of the public universities to cope with the demand for higher education. By the early 1990s the public higher education sector comprised thirteen universities, one Open University, six University Colleges, fourteen polytechnics and a polytechnic higher school. The institutions were spread throughout the country, located in the district capital of each major region. The distribution is not yet even, with 42% of total students in Lisbon, and 62% in both Lisbon and Porto, whose combined population does not exceed one third of the total population (OECD, 1993b).

Some problems persisted though. Overall, the century-old class structure cleavage still exerted a grip on the system. The OECD Review of National Policies for Education, 1984, notes that the higher education system was characterised by a certain "duality", dividing university education from non-university education (where different degrees are awarded and different career connotations in terms of social prestige are associated with each one), old universities, more preoccupied with scientific excellence, from new universities, more concerned with making contribution to regional development, and even dividing university members who obtained their degrees abroad from those which obtained them in-house. This situation had considerable impacts in terms of the overall flexibility of the system, its adaptive capacity to changing conditions and its capacity to exploit synergy, both in educational as well as in research activities. It can be said that this dualistic character is not exclusive to Portugal but the lack of communication between the systems and the close character of each pole makes it a particularly fragmented, non-integrated and rigid system.

Other rigidity problems persisted. University careers are rigid. Once the university teacher is granted the equivalent of a PhD, his/her position in the university is granted for life. This leads to a stratification of the education system, a tendency for closeness, a general lack of co-operation, situations of favouritism, etc. Certain measures were considered to tackle the problems, including a more competitive system regulating the bid for university positions and the implementation of a system of evaluation of the universities, measures and issues that will be addressed in the following years. Those are now the great issues faced by the system, and they follow a general principle of making the structure more autonomous and flexible.

6.7 From 1986 onwards

In 1986 the Basic Law of the Education System (Diário da República, 1986) aimed at ending the somewhat confusing state that the educational system was in (following the pre-1974 politically agitated period) to align it with the new Constitution and to provide clear guidelines and a global framework for the education system. The present system (now under review) is the one created by this law. The main changes relative to the previous system are:

- Enlargement of compulsory education to 9 years.
- Establishment of the principle of democratisation of the educational system (meaning that no discrimination whatsoever is admissible when the individual enters the educational system).
- Rejection of any exclusive link of the public system to any single ideology or religion (this apparently represents the final cut with the Catholic Church).

Other especially important facts in the face of its potential impact on the medium levels of education in Portuguese society (traditionally undervalued as we have seen) are:

- Creation of the so-called professional education, implying a division of the secondary level in two branches: the technical or vocational branch (for those who want to start working after the secondary level) and the general branch (essentially for those wanting to proceed to university level). This is not new, as we have seen, but it is important because it restructures an old principle and practice that was successful in Portuguese society. The concept was regulated in a Decree-Law (Diário da República, 1989).
- The definition and positioning of the polytechnic system (short cycle higher education) within the higher education system and its relations to the professional education.

Since Portugal's accession to EC in 1986, several programmes supported by EC structural funds contemplated training and educational needs, one of which was exclusively concerned with educational issues, namely the PRODEP (Programme for Educational Development in Portugal, 1989-1993). The PRODEP (Table 34) was supported essentially by the European Social Fund and by the European Regional Development Fund. The programme aimed to develop all of the educational system in Portugal, from pre-school education through primary, secondary (with emphasis on the vocational part) and tertiary (supporting the polytechnics and engineering education), development of infrastructures, training teachers and enlarging the role of the Open University.

Table 34. PRODEP execution (1989-1993).

	ECU million (current p.)	% of total
Sub-Programme 1 Physical infrastructure (construction and equipment)	462,7669	41,0%
Sub-Programme 2 Professional education (infrastructure and training)	303,6075	26,9%
Sub-Programme 3 Adult education	68,29585	6,0%
Sub-Programme 4 Higher education	291,2959	25,8%
Sub-Programme 5 Management of the Programme	3,832424	0,3%
Total	1129,799	100,0%

Source: Departamento de Programação e Gestão Financeira do Ministério da Educação (1994).

It amounted to ECU 1140 million at constant 1989 prices (of which approximately 90% was spent during the period of the Programme), of which 59% came from the structural funds of the European Community (61% of which was financed by ERSF and 39% financed by ESF).

As Table 34 shows the great priority was infrastructure development (new schools and equipment). Secondary level vocational education and higher education came next with approximately 25% of the total for each.

The second phase of the programme (PRODEP II, 1994-1999) was approved within the context of the 2nd Framework Programme for Portugal (see section on the economic system and Table 26 on that section), also financed by the ESF and by the ERDF and is now running. It is comprised of five major Sub-Programmes (excluding two dedicated to the management of the Programme). The priorities remain essentially the same.

Table 35. PRODEP II Programme (1994-1999). Main axis of action.

ERFD component:
Sub-Programme 1. Infrastructure development: construction and equipment of schools.
Sub-Programme 4. Infrastructure and development: construction and equipment of social structures in the higher education sector.
ESF component:
Sub-Programme 2. Training of teachers.
Sub-Programme 3. Professional education.
Sub-Programme 5. Higher education.

Source: Ministério da Educação-Departamento de Programação e Gestão Financeira (1996).

Other major programmes had an impact on education and training, although they were directed to R&D activities or sectoral economic development, of which:

- The Science and Technology Mobilisation Programme, a four year programme launched in 1988 and later replaced by the CIENCIA programme, financed 1500 research grants (mostly to university or state laboratories researchers) for a total of about Esc. 1.9 billion (current prices)
- The CIENCIA Programme, a four-year programme launched in 1990 (1990-1993), financed 2600 research grants for a total of about ECU 76 million (source: SECT). It

was replaced by the PRAXIS XXI programme in the 2nd Framework Programme for Portugal that expected to spend ECU 210 million for the same goal (source: Gabinete do Gestor do PRAXIS XXI, 1996).

- The Programme for the Development of Portuguese Agriculture (PEDAP), a ten-year programme launched in 1986, of which one of the objectives was the construction and equipment of several vocational training centres for farmers.
- The Programme for the Development of Portuguese Industry (PEDIP), a five year programme launched in 1988, of which one of the objectives was the training of instructors, technicians and specialists and researchers from industry, to set-up management courses and the development of advanced pedagogical methods, allocating to these activities a total of ECU 215 million at constant 1988 prices (source: Ministério da Indústria e Energia, 1992). Its follower (PEDIP II) expected to spend ECU 347 million at 1994 current prices in various training activities (Ministério da Indústria e Energia, 1994b).

Quantitatively the system has grown considerably, again especially at the tertiary level. Between 1980-1981 and 1993-1994 the number of higher education units has almost doubled with the recent period between 1991-1992 and 1993-1994 registering an average annual growth rate of 8% (well above the GDP growth rate). Presently there are 22 universities (13 public universities and 9 private universities), 15 public polytechnic institutes (short-cycle tertiary education; equivalent to colleges), 31 public higher education schools (short-cycle tertiary level education; equivalent to colleges) and 71 private higher education schools (equivalent to colleges; source: Ministério da Ciência e Tecnologia, 1997). A recent distinctive feature of the system is the increasing importance of the private sector that absorbs now about 30% of total registered students at the tertiary level (INE, 1997).

It seems that finally there is an even distribution of higher education establishments throughout the country (Table 36).

In spite of the unequivocal achievements of the last two decades in upgrading the system it remains to be seen how much of the gap was actually closed, particularly in modern domains of science where multidisciplinary approaches are paramount to the advancement and transmission of science and technology.

Table 36. Geographical distribution of population and higher education units.

	H. Education Units		Population
	No.	% of total	% of total
North	89	32,7%	34,8%
Centre	50	18,4%	17,3%
Lisbon and Tagus Valley	102	37,5%	33,6%
Alentejo	10	3,7%	5,5%
Algarve	10	3,7%	3,7%
Azores	4	1,5%	2,4%
Madeira	7	2,6%	2,7%

Source: INE (1997) for the education units and the Population Census of 1991 published by INE.

The main obstacles are probably to be found in organisational and social aspects of the system rather than in its knowledge contents. It is also an open answer whether the objectives of vocational training and middle level higher education have been reached. In any case, it is perhaps rather too early to assess the overall impacts on society, and particularly on its innovative side.

The available indicators indicate the persistence of old problems of the Portuguese educational system, namely its relative disregard for the medium levels of education. Table 37 represents the situation in quantitative terms. We can say that now primary education (first 4 years) is finally available to everyone, but the situation worsens gradually for the upper levels. Even at the 2nd cycle the enrolment ratio per age group decreases considerably (76%) although the percentage for the next age group (23%) may eventually lead to the conclusion that this cycle is attended by almost everyone. The enrolment ratio in next level (3rd cycle) decreases again substantially (61% now) and drastically at the secondary level (35%).

Table 37. Enrolment ratios per age group and educational cycle.

	6 to 9 years		10 to 11 years		12 to 14 years		15 to 17 years		18 to 22 years	
	1982 (1)	1992 (2)	1982 (3)	1992 (4)	1982 (5)	1992 (6)	1982 (7)	1992 (8)	1982 (9)	1992 (10)
1st cycle	100	100	42.9	24	11.9	5				
2nd cycle			57.1	76	31	23				
3rd cycle					45.2	61		23		
Secondary								35		12
Not enrolled					11.9	11		42		66

Source: Carreira (1996).

Notes: 1st cycle corresponds to primary education (4 years), 2nd and 3rd cycle to basic education (2 years+3 years) and secondary to the final 3 years before university level.

The numbers show that the secondary level remains a weak part of the system. Also, from the numbers of the no enrolled, we can deduce that 45% of those in the age group 12 to 22 years were out of the educational system, which points to a global low level of education of the population as a whole. This picture is confirmed, in terms of comparison with other European countries, by the numbers in Table 38. Table 38 says that 81% of the population (above 25 years old and below 64 years old) possesses only elementary education (from 93% in 1991) and only 18% had attained higher educational levels (from only 7% in 1991). So the considerable investments of the last decades finally succeeded in one thing at last, which was to at least provide elementary education to (almost) everyone. However, both the secondary level and the tertiary level remain very weak and unsatisfactory links in the educational chain. One can wonder if the level of investment has been enough, in view of the initial conditions and in spite of the rate of change in enrolment ratios.

Table 38. Percentage of the population 25 to 64 years of age by the highest completed level of education.

	Pre-primary, primary and lower secondary		Upper secondary		Non-university tertiary and university level education	
	1991	1994	1991	1994	1991	1994
Belgium	57	51	24	27	20	22
Denmark	39	40	43	40	18	20
France	49	33	35	50	15	17
Germany	18	16	60	62	22	23
Ireland	60	55	24	27	16	19
Italy	72	67	22	26	6 b)	8 b)
Netherlands	44	40	37	38	20 b)	21 b)
Portugal	**93**	**81**	**3**	**8**	**4**	**10**
Spain	78	74	12	11	10	15
United Kingdom	35	26	49	54	16	21

Source: OECD (1993a) and OECD (1996a).

a) Does not include non-university tertiary education.

Carreira (1996) argues that the qualitative aspects of the educational system have not accompanied the quantitative development. He points out that many schools are not adequately equipped with libraries, laboratories, sports grounds and other equipment and the universities are no exception to the rule. He seriously questions the preparation of teachers at all levels of education and particularly those at the tertiary level. School drop out rates are extremely high at secondary and higher levels. In the face of these problems there is a policy of evaluation of the educational system that is giving now its first steps. A special (independent) institution (Fundação das Universidades Portuguesas) whose function is to evaluate higher education institutions was created.

Another perspective explains the situation in terms of lack of demand for education as a result of lack of economic capacity of families to pay for the continuation of higher levels of education. Azevedo (1994) says that the percentage of students from poorer families decreases as the educational level increases. Carreira (1996) mentions the reluctance of many families to provide education to their offspring because of economic reasons. However, the fact that more than 30% of higher education students are enrolled in private higher education institutions (because the public system has no place for them) seems to run counter this argument of insufficient demand for education. This situation is partly explained by a deliberate policy of the government to avoid its direct involvement in the economic system (including the educational system), a policy that is typified by the privatisation process and by other liberal policies but it does not invalidate the general argument.

6.8 The education system: a summary

Three main features characterised the education system for a long time: its reduced dimensions, its lack of diversity and its duality. Before 1800, scholastic influence of the church was the main determinant of the system. The stubborn presence of a system that did not evolved perpetuated a cultural cleavage in the society (a very small elite and a mass of uneducated people) which was also related to the feudal-like social and economic relationships entrenched at the time. In spite of the growing importance of the middle class during the convoluted times of the 19^{th} century that marked a phase of transition from a system based on a feudal mode of production to a system based on a capitalist mode of production, its influence or power its not enough to substantially alter the duality of the education system, its rigidity and its reduced dimensions, although the first steps in that direction were done at the time, giving birth to alternatives to the predominant views and creating the seeds for diversity within the system. The scientific paradigm was institutionalised in new universities in the early 1900s after the fall of the monarchic regime and after the institution of a more or less generalised mode of capitalist production, which in itself was facilitated by the crumbling of national internal barriers and the creation of a open national market (cf. chapter 5). The mid-1800s public works on the national communication and transport physical infrastructure substantially contributed to that end as well as creating the need and the awareness for sustained support of badly needed scientific and technological infrastructures, namely at the educational level. After a relatively slow growth of the system the post-2nd World War economic boom and its technological demands finally created the conditions for the growth of the educational sector, still largely characterised by century-old under-investment, rigidity, concentration, dualism and lack of diversity (old characteristics that migrated to the new social actors that embraced the scientific paradigm). The system expanded enormously in the last two decades and the problem of an uneven distribution of educational resources throughout the country seems, finally and to a great extent, surpassed. However, old values prove hard to die, and the expansion of the system masks problems related to the its dualistic character, namely in the existence of weaknesses at the medium level of the system and problems related to rigidities, namely to difficulties in communication flows within the units of the system with potentially important impacts in terms of its multidisciplinary nature. The most important impact for industry has been, and it probably still is, a general shortage of supply of skilled labour and services.

CHAPTER 7. THE RESEARCH SYSTEM

7.1 The background

The research system, much in the way of the educational system described previously, became the victim of its own former success. The climax of Portuguese world power in the fifteenth and sixteenth-century owed much to the contributions made to technical change based on epistemological Aristotelian physics, on geocentric astronomy, on Galen medicine, on the Greek classification logic of pharmacopoeia, on a natural history whose operational references were Aristotle and Plinius, and on an anthropology centred on the classical heritage reshaped by St. Thomas Aquinas. The works of the most renowned Portuguese scientists at the time, Pedro Nunes (1502-1578), D. João de Castro (1500-1548) and Garcia de Orta (1503-1568) are guided and grounded on the set of beliefs and on the conceptual framework set up by Aristotelian physics (Barreto, 1991).

The stock of accumulated knowledge and the conceptual framework that so successfully placed Portugal in a leading position remained firmly encroached and pervasive across the social fabric of the country. The paradigm, fortified by its practical achievements and endorsed by the church, who saw a perfect match between its self-evident, self-consistent character and its own global and universal vision of the world, resisted much of the attacks thrown at it by the small number of marginal intellectuals inclined to adapt the Renaissance spirit and the revolution which was taking shape through the works of its most brilliant apologists.

The epistemological guidelines of the Portuguese scientific community lasted until quite late in the eighteenth-century (Ferraz, 1993), when they were finally shaken by internal social convolutions that deprived the country of one of its most fervent adepts: the Jesuits. The Society of Jesus, which had a powerful position in Portuguese society, controlling virtually every aspect of education, was expelled from Portugal in 1772 and forbidden, from then on, to take any part on the making or function of the educational system, and concomitantly, on the way research was conducted and oriented. The reformation of the university that ensued paved the way for a change in approach to science and technology. The Academy of Sciences, founded at this stage, contributed in many ways, in spite of a turbulent life, to raise scientific awareness and support.

But the changes were to occur at a slow pace and the lack of priority given to education at large and research in particular caused the progressive backwardness of Portuguese science and technology relative to other European countries. The expulsion of the Jesuits is seen by many as a critical blow to the church influence, but Carvalho (1986) argues that the Jesuit expulsion had less to do with different views on education and science than on a serious confrontation of power (involving war between the Company of Jesus and the state) regarding land domination rights in South American colonial territories. The feudal condition of much of the social tissue did not contribute either to the spread of an intellectual confrontational attitude. The situation evolved slowly following the same fate of the educational system: intrinsic resistance to change derived from the social structure, half-hearted attempts to modify the system and political confrontations resulting in steps ahead followed by steps back.

The second half of the 19^{th} century and the first half of the 20^{th} century marked an important point in the advancement, or perhaps in the attempts to advance and update the research system. Several science and technology institutions set-up by private entities concerned with industrial technology and professional training as well as with metrology and quality standards were strengthened. State research laboratories, with similar activities, were restructured and established in the fields of agriculture, veterinary sciences, marine biology and public health. Two new universities were created (cf. previous section), and a quite large number of libraries were established (Silva, 1991). The rationale was two-fold. First, to support and foster the modernisation of the country. Second, to act as means to diffuse a scientific and technological approach to society's problems, in contrast and in opposition to a predominant and powerful literary culture.

This scientific momentum was soon to fade out (but not disappear), because of another change in regime (in 1926), and it only regained its strength decades later. In the interim, the impulse of the momentum contributed to the birth of a couple of research laboratories (the EAN in agriculture, the predecessor of the now INIA, and another one in the health area) including the so-called Board of Nuclear Energy that contributed substantially to the development of competencies and skills in the field of electronics.

The most important institutional measure of this time is probably the creation in 1929 of the National Educational Council (Junta de Educação Nacional) renamed the Higher Institute of Culture (Instituto de Alta Cultura – IAC) in 1936. Its function was to support university research and advanced training. Although "...university research funding was still on a small scale and unreliable these institutions at least granted scholarships enabling a number of students to pursue their studies and research and obtain doctorates in other countries" (OECD, 1986a, p.43).

7.2 The period of economic growth of the 1950s and 1960s

It was during the 1950s that the main state research laboratories were established, prompted more by sectoral policies and demand pressures from various economic groups than by an integrated science and technology policy. Apparently, they were given a prominent role in the research system, according to their share of total R&D expenditure data in 1964. By contrast, the share of the higher education system is quite small at the time.

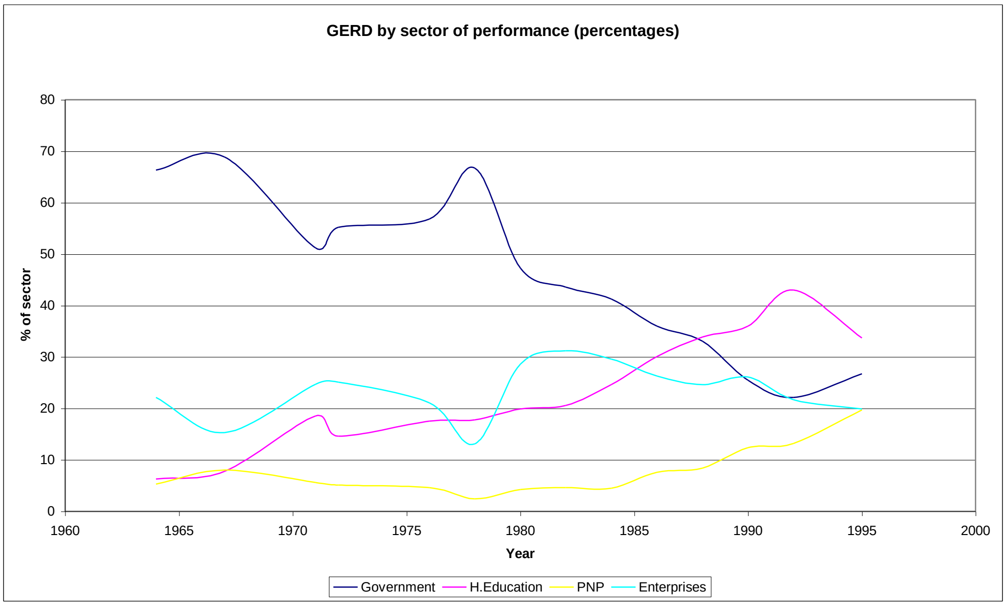
Ruivo (1991) argues that the rationale behind the figures is politically motivated and completely divorced from any science and technology policy. She argues that the creation of separate research laboratories and their relative weight was a premeditated move to secure government control over research and weaken the social role of the university, seen by the political regime as too liberal-minded. There is no available data prior to 1964 that would show a definite trend and confirm the argument but the available one certainly renders itself to that interpretation. It is also in line with the overall picture projected by educational policies and the general fact that the main activities of the universities were educational. But the rationale might be another, namely the fact that priority was given to immediate physical investment and development and thus it was to be expected that the state would invest in research and technological activities that gave quick answers and that could support technically the problems posed by the public works, and not invest in activities with a fundamental research character, geared to long term results and with no immediate practical applications (the type of research more proper to expect from the universities).

Table 39. GERD in current prices, constant price annual growth rates, as % of GDP and by sector of performance (1964-1995).

	%GDP	Current prices	Growth rates at constant prices (%)		Percentage by sector of performance			
		(Esc. Million)	Annual average	Period average	Government	Higher Education	PNP	Enterprises
1964a)	0.28	265.8			66.3	6.3	5.3	22.1
1967a)	0.24	320.4	1.9		68.9	7.8	8.0	15.3
1971	0.38	751.2	19.0	10,5 (1964-1971)	51.2	18.5	5.6	24.7
1972	0.37	854.2	5.5		55.2	14.6	5.1	25.1
1976	0.27	1279.6	-3.9		56.8	17.5	4.6	21.1
1978	0.32	2521.1	13.2		66.7	17.8	2.4	13.1
1980	0.34	4118.5	8.4	8,4 (1971-1980)	47.3	19.9	4.2	28.6
1982	0.35	6541.2	5.4		43.6	20.6	4.6	31.2
1984	0.40	11307.6	5.8		41.3	24.6	4.5	29.6
1986	0.45	19867.6	9.4		36.0	30.1	7.6	26.3
1988	0.50	29910.8	10.2		33.1	33.9	8.4	24.6
1990	0.60	52032.2	16.1	9,2 (1980-1990)	25.5	36.0	12.4	26.1
1992	0.63	80397.8	9.3		22.1	43.0	13.2	21.7
1995	0.60	91878.8	-0.96	8,1 (1990-1995)	26.7	33.7	19.7	19.9

a) Estimated to include social sciences. Source: JNICT and OCT. Note: The ratio GERD/GDP from 1992 on is not strictly comparable with previous years because the methodology to calculate GDP changed.

Figure 6. GERD by sector of performance (%).



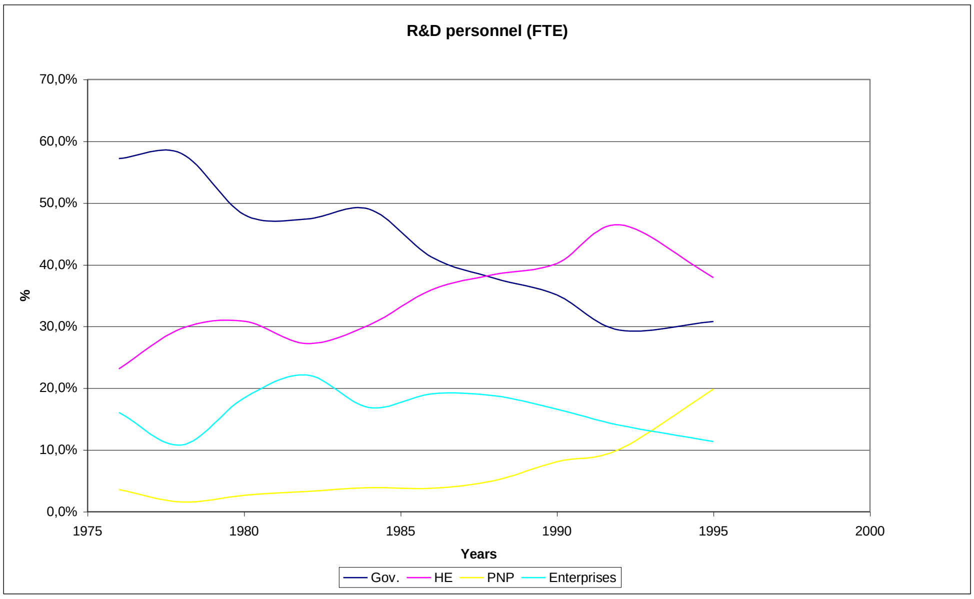
Source: JNICT and OCT.

Table 40. Total R&D personnel (FTE).

	Government		H. Education		PNP		Enterprises		Total
	No.	%	No.	%	No.	%	No.	%	
1976	3845	57,2	1554	23,1	242	3,6	1080	16,1	6721
1978	3797	58,0	1939	29,6	103	1,6	704	10,8	6543
1980	3711	48,1	2378	30,8	202	2,6	1419	18,4	7710
1982	4054	47,4	2330	27,2	278	3,2	1892	22,1	8554
1984	4543	49,0	2799	30,2	361	3,9	1564	16,9	9267
1986	4355	41,2	3799	35,9	401	3,8	2015	19,1	10570
1988	4114	37,8	4182	38,4	545	5,0	2042	18,8	10883
1990	4230	35,1	4840	40,2	976	8,1	1997	16,6	12043
1992	3956	29,4	6249	46,5	1363	10,1	1882	14,0	13450
1995	4790	30,8	5894	37,9	3088	19,9	1768	11,4	15540

Source: JNICT and OCT.

Figure 7. Total R&D personnel (FTE) by sector of performance.



Source: JNICT and OCT.

The research laboratories were under the authority of several ministries, and no institutional mechanism was in place to co-ordinate the research efforts of each one, hence they evolved according to sectoral contingencies. Still within the constrains of a sectoral policy, all of them were reshuffled after 1974, in an attempt to rationalise and concentrate efforts and forge closer links with industry which were quite weak.

The main research laboratories set-up at this period were:

- IICT (Institute of Scientific and Tropical Research), set-up in 1945. It follows a tradition in research that dates back to the previous century. Its forerunner is believed to be the 19th century Cartographic Committee of the Ministry for Overseas Affairs. Research was broadened to include all human and natural sciences.
- LNEC (National Laboratory of Civil Engineering), set-up in 1946. The forerunner was a research centre of the Technical University of Lisbon (cf. previous section). It aimed to give technical support and to conduct research related to a vast programme of public works. Its activity was of great importance when infrastructure development accelerated following the implementation of the Development Plans and its

accumulated stock of knowledge concerning the building of dams and harbours developed considerably.

- INII (National Institute of Industrial Research), set-up in 1957, aimed at providing technical assistance and conducting research in industrial related fields.
- LFEN (Laboratory of Nuclear Physics and Engineering), set-up in 1958. Its aims were to conduct research in civil applications of nuclear energy, and build expertise on the handling of uranium, a mineral resource on which Portugal is rich. Apparently, there are no direct military purposes behind its surge.
- LNIV (National Laboratory for Veterinary Research), set-up in 1957, probably the collation of dispersed bodies. Main areas of research were in vaccine production and animal pathology.
- The Institute of Marine Biology, set-up in 1950. Another institute devoted to fisheries research was latter added to it.

7.3 The role of the higher education sector during the 1950s and early 1960s

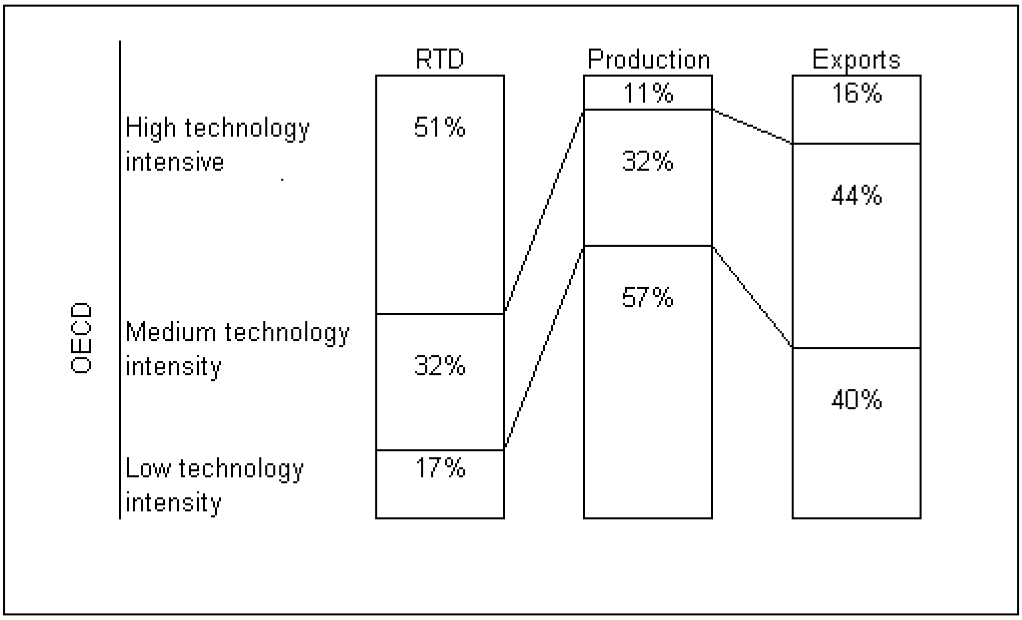
The higher education sector played a minor role during this period (see Table 39 and Table 40). Its (lack of) functionality was partly compensated by the active stance adopted by the Calouste Gulbenkian Foundation that acted as a major research funding institution, filling the profound breaches spread all across the system. Besides funding its own internal science and technology activities it also financed or co-financed, with criteria of excellence, a large number of research projects inside the public universities (Santos, 1988). The international openness of the 1960s and the 1970s enhanced and provided regularity to the inflow of scientific and technological information from abroad, by means of research fellowships abroad and by increasing cultural contact at various levels. The returnees, in turn, found an industrial sector technologically upgraded by the growth of foreign direct investment or licence agreements. Its own scientific and technological demands eventually put pressures on the higher education system and at the political level, ultimately culminating in the Veiga Simão's reform (cf. previous section). It is from the late 1960s that the rising trend of the higher education system becomes visible (see Figure 6 and Figure 7).

7.4 Research in Industry

Interactions between the industrial sector and the social movements and institutional changes obeyed a complex interactive pattern of mutual adjustments and reciprocal influences between the institutional changes taking place in the public and educational sector and the new industrial sectors, the increasing influence of foreign capital and industrial growth in general.

Although most of the industrial innovation taking place was by virtue of inflows of embodied or disembodied foreign technology (Rolo, 1977) through foreign direct investment, inputs of equipment and machinery, licence agreements covering production processes, patents and trademarks, some domestic resources are spent in R&D activities, but they were low in absolute terms (see Table 39, Table 40, Figure 6 and Figure 7) and they represented only a share of the resources spent in purchasing foreign technology. In 1980 they amounted to 25% of expenditures in foreign technology (Rolo et al, 1984) and in 1990 they amounted to 79% of purchases of foreign technology (OECD, 1993). In a study of a large number of licence contracts (2534 contracts), 50 per cent were included in the "turn-key" type and its authors (Rolo et al., 1984) argue that severe restrictions related to procurement, production, distribution, markets and post-contract obligations, and the weak concern by the licensees with the rationality of acquisition and application of technology, its high degree of commercial protection and an almost non-existent reproductive capacity rendered in the contracts not much room for developing indigenous technological capacity and diffusion. Simões (1994) explains the pattern arguing that the motives behind licence agreements were market-driven and not technology-driven. These assertions bring us back to the arguments of the competence of the industrialists. Once again we can argue that the strategy followed by the industrialists, as a whole was perhaps not the most efficient one (if we compare the strategy followed by the industrialists in other newly industrialised countries especially in the Asian region). The weight of the capital goods sector remains relatively weak which, combined with its lack of autonomy (large parts are foreign owned), adds to its relatively weak impact on other industrial sectors and on other parts of the technological system and, generally, on the development of domestic potential.

Figure 8. Relation between R&D expenses, production and exports.



Source: Caraça (1993).
Notes:

1) RTD+TT includes expenses with technology acquisition (TT)

2) Data for OECD countries concerns the period 1970-1980. Data for Portugal concerns 1982.

Caraça (1993) notes the low participation of technology-intensive sectors in the total output of the country, in 1982, as well as on total exports (Figure 8) and the fact that more than two thirds of exports are supported by only 15% of total R&D and only 8% of domestic R&D. Figure 8 is based on OECD (1986b) and the comparable data referring to Portugal is based on Gonçalves et al (1986). The comparison of Portugal with the eleven OECD countries on which the data is based show a more favourable pattern relating

R&D, production and exports and illustrates the relative standing of Portugal at this time with respect to industrial research.

7.5 The establishment of JNICT in 1967

Government intervention in science and technology is widely perceived as a vital element in the causation, direction, nature and pace of technical change (Nelson, 1984; Nelson 1993; Lundvall, 1992). The establishment of JNICT (National Board for Scientific and Technological Research) in 1967 is perhaps the most visible institutional sign of the growing awareness of the impacts of science and technology on Portuguese society. The function of JNICT was to plan, to co-ordinate, to finance and to promote scientific research, with a prominent central role. But, since its outset, it has encountered major obstacles and resistance, including the absence of a strong political will, the absence of funds and the resistance of other research institutions. The responsibility for JNICT was moved back and forth between the Ministry of Education and the Ministry of Economy for several years until 1986, finally stabilising under the (non-sectoral) Ministry of Territorial Planning and Administration, when it acquired a new status and importance.

In its early days the instability of JNICT reflected a period of learning and "digestion" of international experience in science and technology policy, experimentation on, and gradual consolidation and definition of, priorities, mechanisms and approaches to domestic science and technology policy. In the meantime, while this process of maturity was taking place, it fulfilled two important roles:

– It acted as a "middleman" and co-ordinating body regarding international co-operation in science and technology. Two permanent commissions were set-up to deal with NATO (INVOTAN) and with OECD and the European Community (COCEDE). In 1971 Portugal participated for the first time in R&D co-operation with other Europen countries through the programme COST.

- The systematic collection of quantitative data concerning the national science and technology potential through biannual surveys, making available for the first time an indispensable statistical tool for decision-making.

7.6 Changes in the higher education sector and in the public sector in the 1970s and early 1980s

The higher education sector expanded considerably during this period (see Table 39, Table 40, Figure 6 and Figure 7), broadly following the principles of Veiga Simão's reforms, which argued that the function of the higher education system should be much more than educational. The main problems affecting research at this time were:

- A dual system of university funding and responsibility. The university authorities (rectors, deans, heads of departments, etc.) are responsible for teaching and teaching policy, staff recruitment, management and to some research directly linked to education activities. R&D activities, in the strict sense, are conducted under the responsibility of research centres funded and attached to an outside, central institution (the INIC, National Institute for Scientific Research, set up in 1975, after an overhaul of the High Culture Institute - IAC). The shortcomings of these dual system are that the universities do not have a formal say on their own research policy (in the sense that they do not fund the research done by their members) and the INIC is unable to formulate a human resources policy since it has no say on the careers of the university personnel.
- An excessive dispersion and fragmentation of research centres resulting in critical mass not being attained.
- Funding is almost exclusively devoted to current expenditure on personnel which together with low salaries, often pushes university teachers to seek extra jobs, makes research almost impossible.

- Insufficient links between university research and industrial research, steaming from the lack of confidence of industry in the capability of university research to produce timely and exploitable outcomes.
- Insufficient links between university research and state research laboratories.
- Infrastructure weakness in equipment, buildings and libraries.
- The lack of a well-formulated and accepted science policy and the resultant inability to plan the scientific development of the universities coherently.
- A very rigid organisational structure and functioning.

The government sector still accounts for the largest share in total R&D expenditure and R&D personnel but an accelerated decreasing trend is visible since the late 1970s (Table 39, Table 40, Figure 6 and Figure 7). A reorganisation of the research laboratories took place, collating several laboratories and restructuring others. The aim was to rationalise the allocation of resources, avoid dispersion of institutions and enhance close links with users (industry and agriculture). The following state research laboratories were created:

- LNETI (National Laboratory of Industrial Engineering and Technology) The INII and the LFEN were brought together to form this laboratory.
- INIP (National Institute for Fisheries Research) formed by grouping the Institute of Marine Biology and the Office for Fisheries Studies.
- INIA (National Institute for Agricultural Research). The EAN and other smaller institutes formed the INIA.

Some of the state laboratories established their own reputation as centres of excellence, of which LNEC, the National Laboratory of Civil Engineering, and IICT, the Institute of Scientific and Tropical Research, are the most outstanding examples. They self-finance approximately half of their activity through research contracts. The others, as a general rule, have yet to forge closer links with users, and more specifically LNETI that was supposed to support industry. Each state laboratory is under the responsibility of a specific ministry.

According to the OECD Review of National Science and Technology Policy published in 1986 the Portuguese scientific and technological system seemed to be very rigid and sectoralised with the exception of JNICT. There was a severe problem of communication and co-ordination. Each ministry had a certain budget to allocate to research and development activities in the state laboratories under its responsibility. The allocation of resources was made with no consultation with other ministries. “There is no inter-ministerial procedure to enable a rational scientific budget to be analysed, negotiated and approved. Each ministry is responsible for organising and managing its own research activities which in general are - or rather, should be - co-ordinated by a central institute or laboratory” (OECD, 1986, p.36-37).

7.7 The impact of accession to EEC on the S&T system

Since the accession to EEC in 1986, the science and technology system has undergone major changes. The GERD/GDP ratio which for more than two decades fluctuated sharply around 0.25-0.4 has shown a rising trend since 1984, at least until 1992. The number of researchers and higher education students has risen, new research laboratories were created (such as the CTQB, set up in 1988, conducting research in the fields of chemistry, biochemistry, biotechnology, microbiology and biophysics, and the CNIG, set up in 1989, providing extension services and conducting research related to the management of natural resources and geographical information systems), and the overall science and technology infrastructure was enlarged. Several institutional changes have settled down, with potential to strengthen the much needed interactions and information flows between the main sectoral actors playing a role in the process of technological change and innovation. All this activity was considerably boosted by the financial aid and the policy orientation of the Community formalised in a series of specific programmes for Portugal, financed primarily by the structural funds of the community (see details below).

But there are distressing signs. The most disturbing is the fact that the share of business expenditure on total R&D has been falling after showing an upward trend during the early 1980s. On the other hand, and in the face of the most recent statistics on the S&T system (OCT, 1997) showing the decrease of the ratio GERD/GDP from 0.63 to 0.6, reverting the country to the 1990 level of expenditure relative to GDP, one has doubts about the firmness of the political will behind the recent upsurge which has yet to be proven a constant and reliable driving force, and doubts exist as to whether they are driven by a clear and coherent strategic commitment or rather by circumstantial events.

7.8 A novelty in the national S&T system: major research programmes

A major change, relative to previous policies, was the introduction in the mid 1980s of major research programmes. Of the programmes described below, two of them are exclusively concerned with R&D activities, namely the PMCT and the CIENCIA.

The first one was the Technological Development Plan (PDT) with ambitious goals, which aimed at improving the overall S&T system, and particularly those parts of the system at the interface between state research institutions and industry. To promote links between industry and research institutions the plan envisioned the creation of technological parks, R&D enterprises, innovation agencies, training and information for industry, technological services, etc. Some initiatives were brought up and others were eventually transferred and continued under the auspices of PEDID (see below). The plan was elaborated by LNETI, itself under the authority of the Ministry of Industry.

The Science and Technology Mobilisation Programme (PMCT), was launched in 1988 and the realistic aim of the five-year programme was just to induce a boost in the S&T system so as to push it in a direction that could contribute to the modernisation of the country. It financed advanced training, by providing fellowships and research contracts on specific priority areas. It was accompanied by ex-ante assessment, interim and ex-post evaluation. The plan was elaborated by JNICT, under the authority of the Ministry of Planning.

The CIENCIA programme followed next. It was a four-year programme, financed by the EC and the Portuguese government whose contribution was 36 per cent of the total. The main objective was to strengthen the scientific and technological infrastructure both in the public and private sector, by supporting the establishment or the upgrading of laboratories, major equipment, computers, data banks, etc. The second objective was to provide advanced training, through the award of fellowships. The fellowships were preferentially granted to researchers with no links to the government sector, hoping that they would eventually enter the private sector. There were also major concerns regarding the development of multidisciplinary disciplines and sectors and in favouring less advanced regions. The CIENCIA programme was administered by JNICT.

The PEDIP programme was a programme directed towards the industry. It was a large ECU 1.7 billion five-year programme whose objectives were to reinvigorate the industrial base and to create and develop new industries. It consisted of several sub-programmes vertically and horizontally articulated one of which was addressed to research and development activities. A new edition of PEDIP was approved recently. The PEDIP programme was administered by an office linked to the Ministry of Industry.

The PEDAP programme was aimed at the agricultural sector. As the PEDIP programme it concerns the whole sector and not only R&D. It was approved in 1986 as a ten-year programme, 77 per cent of which financed by the EC and a new edition was also approved. Among its objectives, those more close to the innovation system are the creation of training centres for farmers, agricultural teachers and advisors, and to promote feasibility studies or interconnected studies aimed at assessing strategic and structural priorities for the development of the sector. The main contribution to research was the creation of a new state research laboratory, the CTQB, mentioned earlier, to conduct research in the modern field of biotechnology. The programme was administered by an office linked to the Ministry of Agriculture.

7.9 Major institutional changes and steps to increase the co-ordination of the system

A Law on R&D was passed in 1988 (Diário da República, 1988) stating the main objectives that should, in principle, set the guidelines for a coherent science and technology policy. It states that scientific research and technological development are "national priorities" involving the "public, private and co-operative sector" and it aims to strength the overall S&T system in its multiple facets. It sets a ten-year target to reach a GERD/GDP ratio of 2.5% (we can now see how distant we are from this target and the misguided notion of priority embodied in the letter of the Law), and defines criteria to be followed in the fields of R&D evaluation.

To a newly created Secretariat of State for Science and Technology (SECT) placed under the authority of the Ministry of Planning and Regional Administration was given, in 1986, the responsibility of global co-ordination of the national S&T system. The move should be interpreted as a shift from the previous sectoral approach to S&T policies. Among the duties of SECT was the responsibility to elaborate a three-year medium term planning document containing the broad lines of policy and actions to be undertaken. The plan has effectively been issued regularly but, although it contains interesting and useful analysis of the S&T system, it lacks quantitative targets. Furthermore, the science and technology budget introduced in 1987/1988, which should be a logical extension of the planning procedure, has remained more an accounting exercise than an instrument for "...playing a decisive central role in shaping and guiding the government research policy" as recommended by the OECD review of 1986.

Another institutional measure at this time was to revive the idea of a collegial body that would advise the government in all questions concerned with science and technology policy, financing, evaluation, co-ordination, etc. A previous council was set up in 1982 but it never fulfilled its functions. The new council, the High Council for Science and Technology (Conselho Superior de Ciência e Tecnologia), was composed of approximately sixty people, headed by the Minister of Territorial Planning and

Administration and representatives of other ministries, of the autonomous regions of Madeira and Azores, of the state research laboratories, of the universities, the polytechnics, the private non-profit associations and industry.

During that time, JNICT increasingly took the role of the major financing institution for R&D activities. Its budget increased more than 12,000 per cent since 1982, managing in the early 1990s about one third of the total national R&D budget (OECD, 1993). Under a new legal regime which gave it financial and administrative autonomy, JNICT was put under the responsibility of SECT acting as its executive body, with responsibility in planning, co-ordination, support and evaluation of the S&T system, following the broad guidelines provided by the medium-term planning documents. Internal restructuring rearranged some of its consultative councils, by creating sectoral consultative research councils. The main consultative council of JNICT now includes the chairmen of the sectoral research councils and representatives of the sate research laboratories, universities and industry. New powers were given to JNICT related to R&D and innovation, namely, in encouraging R&D and innovation programmes through R&D contracts and in promoting the development of major research infrastructures, according to sectoral needs and in collaboration with the state research laboratories.

Recently, with the change of government in 1995, new steps were taken that apparently point to a greater priority given to science and technology policy matters. The most important is that a Ministry for Science and Technology was created replacing the Secretariat for Science and Technology (SECT) mentioned above which was under the responsibility of the Ministry of Planning and Regional Administration. JNICT was the most important institution placed under the authority of the new Ministry. Its restructure led to its extinction (Diário da República, 1996). In its place were created three institutions:

- Observatório das Ciências e Tecnologias – OCT, (Observatory of Science and Technology), whose tasks are: to collect, process and diffuse scientific and technological information; to advice on the preparation of the annual R&D budget; to elaborate planning documents and to monitor progress in the goals set up by the plans;

- Instituto de Cooperação Cientifica e Tecnológica – ICCT, (Institute for Scientific and Technological Co-operation), whose task is to help the Ministry of Science and Technology in all tasks related to RTD activities involving relationships of Portugal with other countries;
- Fundação para a Ciência e Tecnologia – FCT, (Foundation for Science and Technology) whose task is to manage and finance programmes related to the development of the national S&T system.

Basically, the Observatory substitutes the statistical and planning service of JNICT, the Institute substitutes JNICT in the management of international relations and the Foundation substitutes JNICT for the management of strictly national programmes. Additionally the Ministry got the responsibility for a number of other institutions including the Academy of Sciences and two state research laboratories: the Instituto de Investigação Científica e Tropical (Institute for Scientific and Tropical Research) an institute with a certain reputation in the field of tropical agricultural products research with many connections to Portuguese speaking countries and other less developed countries, and the Technological and Nuclear Institute. The other research laboratories remained under the responsibility of the sectoral Ministries.

Recent actions of the Ministry followed three main vectors:

- the management but also the restructure of the existing programmes related to research and technological development, of which the most important is the PRAXIS XXI programme follower of the CIENCIA programme (see below)
- the commitment and attempts to adopt an holistic perspective of the public research laboratories and the research centres, the institutes and the technological parks created under the CIENCIA.

– an horizontal intervention aimed at popularising, diffusing and stressing the importance of scientific and technological culture throughout society with a particular emphasis on the information technologies as a strategic mean to achieve that goal.

The main decision under the first vector was to restructure the PRAXIS XXI programme. Unlike the CIENCIA programme whose main priority was on investment in physical infrastructure (asides from advanced training), the priority of PRAXIS XXI is now at the level of research projects with a preoccupation to link that research effort to economic uses, i.e., to support research projects involving academia, enterprises and technological centres. The differences in priorities are visible in Table 41 and Table 42. While almost 75 % of total funds of the CIENCIA programme were devoted to physical infrastructures, the PRAXIS XXI programme devotes only about 23% of total funding to physical infrastructures. The rationale behind it is that the CIENCIA programme managed to equip reasonably if not considerably well a large part of the research community. The problem was now to make effective and efficient use of that equipment, a consideration often raised in the evaluation reports of independent teams that visited regularly the research centres financed by the CIENCIA programme. It was also an issue raised by students of comparable S&T systems in Europe subject to similar circumstances and events (Tsipouri, 1992). The CIENCIA programme devoted 25% of its resources to advanced training and a high priority for advanced training continued under the PRAXIS XXI programme.

Decisions under the second vector of activity of the new Ministry followed also the concerns about the effective use of the resources devoted to R&D. The tendency is to increase selectivity even more than in the CIENCIA programme.

A natural corollary of this philosophy is the implementation of evaluation procedures which the Ministry recently undertook covering all 260 research centres created by CIENCIA (OCT, 1996) and a global evaluation of the eight state research laboratories (dispersed under the responsibility of sectoral ministries). Concerning the state research laboratories, in its first phase the evaluation will cover only the strictly called state research laboratories but other institutions will be looked at (such as the newly created Institutes under the aegis of the CIENCIA programme) in an attempt to have a global and comprehensive perspective of the strengths and weaknesses of all the public research system. The 260 research centres will be financed on a multi-annual basis according to the demands of the centre and evaluated according to the success of the objectives stated in the centre programme. Measure 2 of the PRAXIS programme is also a highly selective measure aiming to support large research programmes involving relatively few research centres deemed to be excellent.

The importance given to science and technology parks was scaled down under the directives of the new Ministry of Science and Technology and the efforts are to be concentrated in two parks, the Taguspark in Lisbon (which is now the most developed) and the Science and Technology park in Porto (still in a very initial state of development).

The main responsibility for the management, administration and strategic decision-making of the Taguspark fall in the hands of academia and a few large public enterprises, after a confrontation between an alternative view that supported a more widespread and balanced involvement of firms and academia.

Table 41. The CIENCIA Programme (1990-1993).

Sub-programmes	Measures	Funding (ECU million)
I- Development of R&D infrastructures in priority domains	A-Information technologies and telecommunications.	35
	B- Production and energy.	23
	C- New materials.	17
	D- Health.	20
	E- Agriculture.	15
	F-Biotechnology and fine chemistry.	15
	G- Marine science.	7
	H- Reinforcement of R&D infrastructures in priority domains.	10
	Sub-total:	142 (46.7% of total)
II- Advanced training and innovation in priority domains	I – Advanced training	56
	J- Support of innovation in firms	5
	L- Creation of an Innovation Agency	15
	Sub-total:	76 (25% of total)
III- Global support to the scientific and technological system	M- R&D infrastructures in the exact sciences and in the engineering sciences	20
	N- R&D infrastructures in the earth and environmental sciences	7
	O- R&D infrastructures in economy and management sciences.	4
	P- Common use R&D infrastructures.	15
	Q- Infrastructures for popularising R&D	9
	R- General training in science and technology.	21
	Sub-total:	76 (25% of total)
IV- Management of the Programme	S- Technical support	7
	T- General support to the management of the programme	3
	Sub-total:	10 (3.3% of total)
	Grand Total	304

Source: SECT (1990).

Table 42. The PRAXIS XXI Programme (1994-1999).

Measures	Actions	Funding (ECU million)
1. Reinforcement of infrastructures	1.1 R&D laboratories	46
	1.2 Common use R&D infrastructures	46
	1.3 Science and Technology Parks	28
	Sub-total:	120 (22.8% of total)
2. Development of the base of the S&T system	2.1 Structural programmes for the development of the base of the S&T system	56
	2.2 Stimuli to the internationalisation of the S&T system	21
	Sub-total:	77 (14.6% of total)
3. Mobilisation of the S&T capacity for innovation and regional development	3.1 Programmes for strengthening technologically the enterprises	50
	3.2 Programmes for strengthening the S&T development of less favoured regions	30
	3.3 Stimuli to technological diffusion and innovation	14
	Sub-total:	94 (18.1% of total)
4. Advanced training of human resources	4.1 Advanced training to reinforce the base of the S&T system	135
	4.2 Advanced training for applied research, innovation and regional development	75
	Sub-total:	210 (40.1% of total)
5. Technical support(ERDF)		15
6. Technical support (ESF)		8
	Sub-total:	23 (4.3% of total)
	Grand Total	524.969

Source: Gabinete do Gestor do PRAXIS XXI (1996). Note: the calculations were made using three decimal places. The numbers are presented with no decimal places (except the grand total) for ease of comparison with the CIENCIA programme.

7.10 Private non-profit institutions and other mechanisms to support innovation

The last years have also witnessed a changing pattern in the national S&T system, which is the proliferation of private non-profit institutions. The share of R&D accounted for PNP on total R&D is now the highest in the OECD area (19.7% in 1995; see Table 39). The early major PNP was the Caloust Gulbenkian Foundation that has played (and continues to play) a very important role in the upgrading of the S&T system. The more recent ones are the result of government support for this kind of institution, as stated in the major programmes described earlier, so as to implement mechanisms aimed at supporting industrial innovation. The 1993 OECD Review of S&T Policy tentatively classifies them as foundations, institutes and associations. The distinction between the three categories is however difficult to define. Most of them are associations of business, universities and state research laboratories. The foundations are legal independent entities and can be privately or state financed. The foundations and institutes are financially autonomous, the associations are confined to the financial management of research contracts.

Many of the mechanisms envisioned by the major research programmes aimed at building bridges between industry and other research institutions have already been launched and they are generally financed both by government and by industry under the aegis and the guidelines of the major research programmes. They include an innovation agency, two technology parks (finance for another two parks has been approved but, as mentioned earlier, the guidelines for the implementation of science parks have changed under the directives of the new Ministry), one R&D enterprise in the field of electronics and another in biotechnology, nine sectoral technology centres[5], venture capital corporations (the first ones financed under PEDIP), and several institutes for new technologies, incubation centres, technology transfer centres and demonstration units. However, and in spite of this array of physical infrastructures there are few if any

[5] Industrial sectors covered: textiles and garments, ceramics and glass, mechanical industries, cork, wood and furniture, shoes, leather, moulds and special tools, ornamental rocks

systematic studies of their activities and impacts on the innovation capabilities of the system, and particularly on firms.

7.11 Some general remarks on the recent evolution of the system

In spite of the considerable achievements of the system in recent years the situation remains deficient both in its structural configuration and if comparisons are made with other countries.

The distance of Portugal from other EU countries is still considerable (Table 43). The ratio GERD/GDP is below one third of the EU average and almost one fourth of the OECD average. The ratio R&D personnel/active population is also approximately one third of the EU average although the ratio total researchers/active population fares a little better, but it is still approximately half of the EU average. The comparative discrepancy between these two last indicators reveals a structural weakness and/or feature of the Portuguese system, that is the low ratio of other R&D personnel/researchers. Once again, the dual nature of Portuguese society, visible in other parts of the system (notably in the education system, but also in social stratification) and mentioned in earlier sections of this work (cf. previous sections) reveals itself.

A distinctive feature of the system is the low share of the enterprise sector in GERD compared with other EU or OECD countries. According to these numbers it is now the country whose enterprise sector has the lowest share in GERD, considerably distant from Spain to which often it is compared. Only Greece has a similar pattern.

Table 43. R&D resources: international comparisons.

	GERD/GDP	R&D expenditure percentage by sector of performance				Per 1000 of active population	
		Government	Enterprises	H. Education	PNP	Total R&D personnel	Total researchers
Belgium (1991)	1,66	6,1	66,5	26,2	1,2	9,5	4,3
Denmark (1)	1,8	17,8	58,3	22,8	1	9,5	4,7
France (3)	2,38	21,1	61,6	15,9	1,4	12,5	5,8
Germany (2)	2,27	15	66,1	18,9		12	5,8
Greece (1993)	0,6	32	26,8	40,7	0,6	3,5	2
Ireland (1993)	1,24	10,4	67,8	21	0,8	6,8	4,7
Italy (1995)	1,13	22,1	57	20,9		6,2	3,3
Netherlands (1993)	1,87	19,4	53	24,9	2,7	9,7	4,3
Portugal (1995)	**0,6**	**26,7**	**19,8**	**33,8**	**19,8**	**3,3**	**2,4**
Spain (2)	0,91	19	51,1	28,9	0,9	4,8	2,8
United Kingdom (3)	2,19	13,8	65,2	17,5	3,4	9,9	5
EU average	**1,91**	**16,6**	**62,1**	**20**	**1,4**	**9,4**	**4,6**
United States (2),(4)	2,45	10	71,1	15,4	3,5	-	7,4
Japan (1994)	2,9	9	66,1	20,2	4,7	14,2	9,9
OECD average	**2,15**	**12,9**	**66,7**	**17,5**	**2,9**	**-**	**5,5**

Source: OECD (1995 and 1996c).

Notes: (1) 1995 for GERD/GDP, 1993 for the other data.
(2) 1993 for R&D personnel, 1995 for other data.
(3) 1993 for R&D personnel. 1994 for other data.
(4) Excluding, partially or totally, capital expenses.

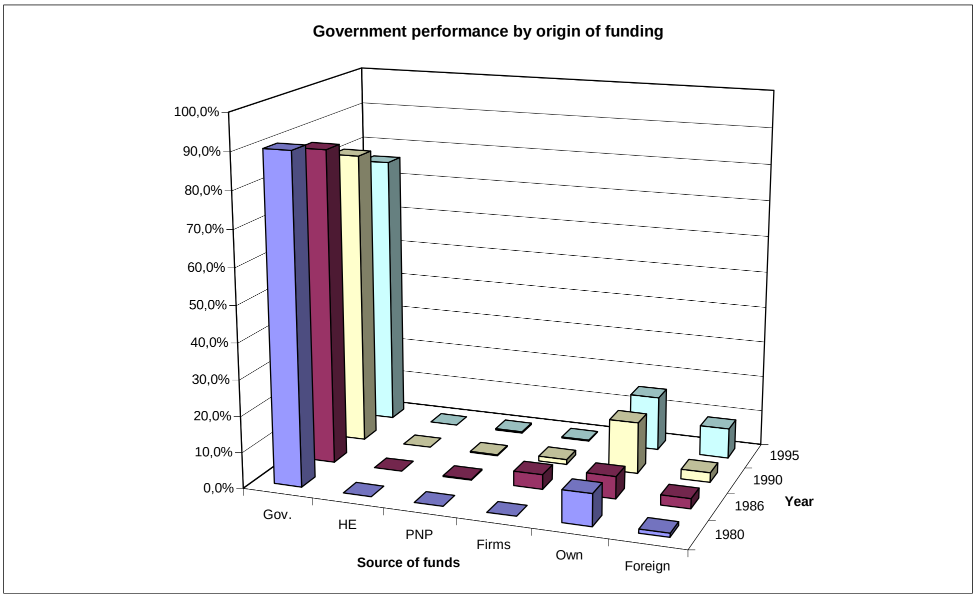
Another distinctive feature is the high share of PNP in GERD, the largest (by a large order of magnitude) in the EU or OECD area. If the PNP share is spent in activities close to the enterprises and the market, it is then a compensation for the low share spent by the enterprise sector and it will represent eventually an unique way of allocating R&D resources in downstream (close to the market) activities. However, an analysis of the source of funds of the PNP institutions does not seem to support such a view (see below).

The fact that GERD as a % of GDP fell between 1992 and 1995 reveals much about the level of priority that science and technology matters receive. Once again, as seems usual in Portuguese history, the written targets (in this case we are referring to the 1988 law on R&D) do not express themselves in deeds, and represent merely manifestations of intentions and not programmes of action. The same goals related to the development of the C&T system and specifically the closing of the gap that exists between other European countries and Portugal are once again present in the Government Plan for 1997 (and for 1996 and 1995) but it remains to be seen what level of priority and investment is ascribed to science and technology.

The last available statistics show that the national investment in S&T is being replaced by EU investment, instead of the latter being an addition to national investment (see Figure 9, Figure 10, Figure 11 and Figure 12; the table with the exact numbers from which the graphs were constructed is in Annex E).

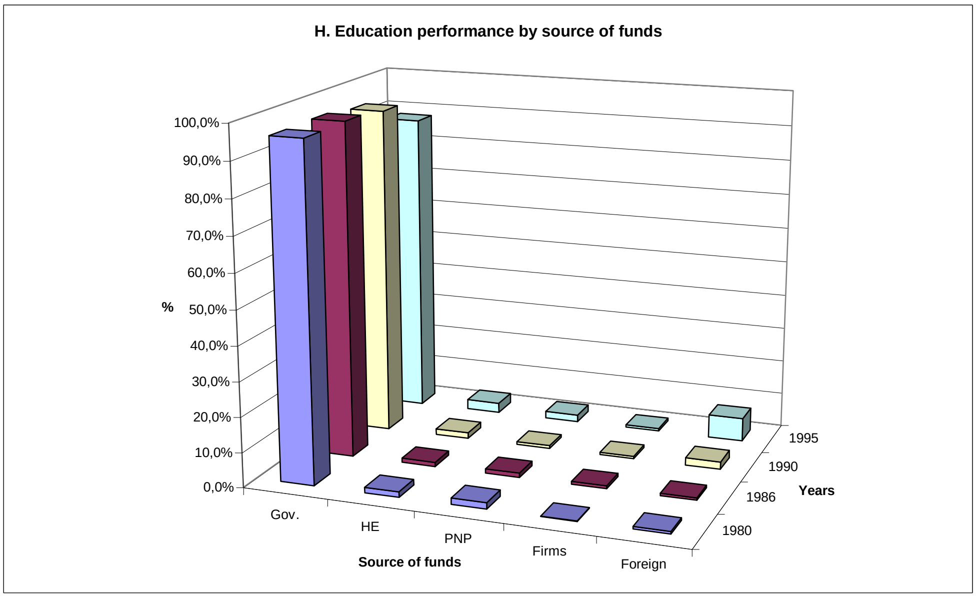
The trend is especially visible in the government sector and the higher education sector whereby a proportional decrease of funds from the government is accompanied by a proportional increase of funds from abroad. The source of such funds is obviously linked with the structural programmes funded by the European Union. This trend is also visible in the enterprise sector and in the PNP sector. Consideration should also be given to the recent perspective of the Ministry of Science and Technology which seems to have ascribed an excessive importance to supporting a limited number of excellent groups (and thus reverting again to an elitist perspective of the system), although it remains to be seen how far it will pursue this policy.

Figure 9. Government expenditure in R&D by source of funding.



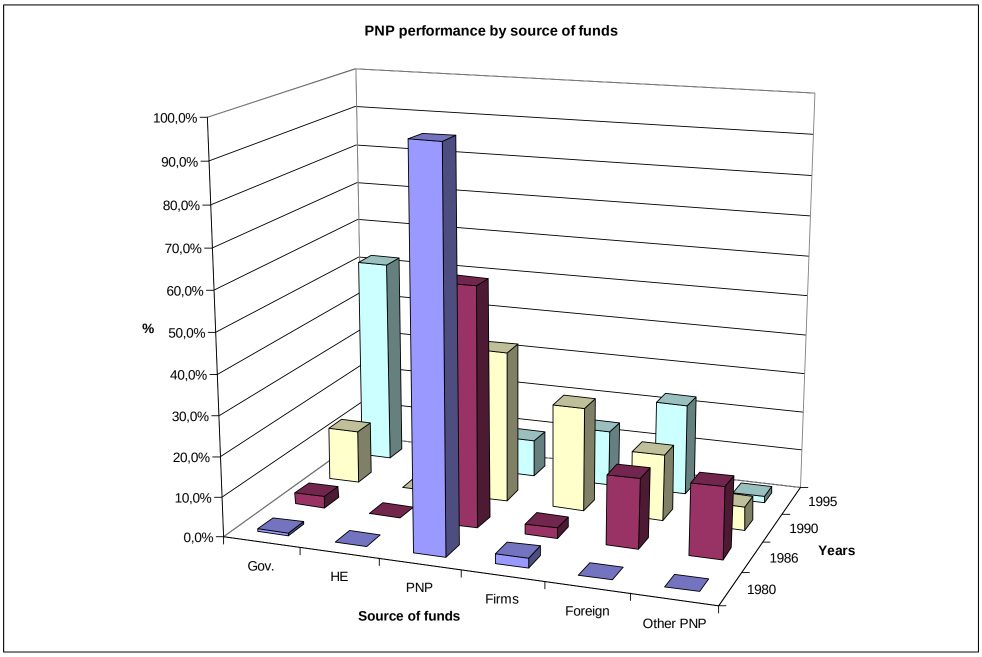
Source: JNICT and OCT.

Figure 10. Higher Education expenditure on R&D by source of funding.



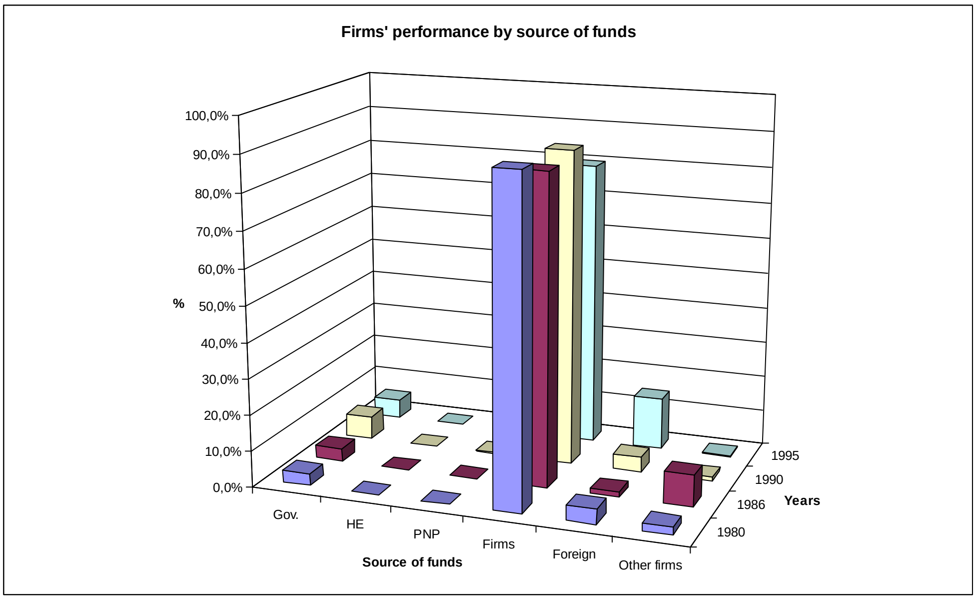
Source: JNICT and OCT.

Figure 11. PNP expenditure in R&D by source of funding.



Source: JNICT and OCT.

Figure 12. Enterprises expenditure in R&D by source of funding.



Source: JNICT and OCT.

Another worrying characteristic is the relative closeness of each sector relative to the others. Each sector mainly self-finances its own performance and contributions from other sectors are marginal or non-existent. Even in the enterprise sector, which was subject to major investment programmes since 1989, namely the PEDIP, and where consequently one would expect an increase in funding from the part of the government, the trend is for a decrease in extra-sector funding. Since the level of investment in BERD is so low in Portugal the fact that subsidies for R&D investment put at the disposable of enterprises are not utilised reveals the low level of priority attached to those investments.

The situation of the PNP institutions is intriguing. Originally, the policy intention behind the legislation that facilitated the existence of such institutions and the creation of new ones (generally by university members and close to higher education precincts) was to enhance and facilitate the links between academia and industry. The evolution of the performance of these institutions by source of funding seems to indicate that they are deviating considerably from their original intentions. As Figure 11 shows R&D activities performed by their own funds was drastically reduced from a proportion of 90% in 1980 to less than 10% in 1995. On the other hand funds from the government increased dramatically from 0.6% in 1980 to 51.2% in 1995. It is pertinent to say that these institutions are less and less private and more and more public. Funding from firms is still at a reduced level and shows no robust trend. What lies behind these numbers is open only to conjecture because, to the author's knowledge there are no studies addressing this problem. According to occasional press reports and informal sources of information the underlying causes might be related to lack of demand from the enterprise sector and to subsequent government intervention or redirection of funds from other governmental sectors to avoid financial collapse. Foreign (most probably EU) funding has also been an alternative way to cope with funding shortages.

The perennial problem of (lack) of diffusion of resources and technologies throughout the entire society continues to characterise and to condition the system. Major programmes like CIENCIA, PRAXIS and PEDIP have specifically addressed the problem and have favoured explicitly less favoured regions of the country but the system remains quite unbalanced (Table 44).

Table 44. Regional distribution of R&D resources in 1995.

Region	GERD		R&D Personnel		% of total population	Total R&D personnel per 1000 active population
	Esc. Million	% of total	FTE	% of total		
North	18954.7	20.6%	3559.3	22.9%	35.6%	2,3
Centre	13821.2	15.0%	2154.2	13.9%	17.3%	3,0
Lisbon and Tagus Valley	52608.0	57.3%	8529.0	54.9%	33.4%	5,5
Alentejo	2187.7	2.4%	437.7	2.8%	5.3%	2,0
Algarve	976.6	1.1%	225.8	1.5%	3.5%	1,5
Azores	1277.3	1.4%	225.4	1.5%	2.4%	2,6
Madeira	2053.3	2.2%	408.6	2.6%	2.6%	3,9
Total:	91878.8	100.0%	15540	100.0%	100.0%	3,5

Source: OCT (1997) and INE (1994 and 1997).

The region of Lisbon and surroundings concentrates 57,3% of GERD and 54.9% of FTE personnel whilst its population is only 33.4% of total, i.e., much more than half of total resources are concentrated on one third of the total population of the country (OCT, 1997). In 1988 the share of GERD allocated to the region was 67%. The government sector is the one that contributes more to that concentration with 82% of government expense in R&D allocated to that region. It reflects the excessive concentration of the state research laboratories. Since the state research laboratories are still the main vehicles for technology transfer to industry, such a concentration is rather negative in terms of diffusion and industrial innovation. Perhaps not coincidentally, the PNP sector and the enterprise sector are also quite concentrated in this region, with 52% of PNP expense in R&D and 50% of enterprise expense in R&D allocated to the region. The higher education sector is the less concentrated (with 42% of higher education expense in R&D allocated to the region) but it is nevertheless disproportionate according to the share of total population (33,4%). In spite of this concentration of resources not even the Lisbon and Tagus Valley region reaches indicators of R&D resource intensity close to EU or OECD averages.

7.12 Industrial research: additional comments

The explanation of the funding pattern of PNP institutions leads us to the analysis of the enterprise sector. The lack of demand of R&D activities[6] by the enterprise sector may be due to a general retraction on the part of the firms in R&D investment due to the recession of 1991-1993, which would also explain the proportional decrease in GERD (Table 39) and the absolute decrease in R&D expenditure in the enterprise sector (Table 45). The decreasing share of industrial employment in total employment is also an explanation, but since the numbers are so low one may wonder if that is really the explanation, since the decrease in industrial employment affects more the production workers and less the research/development side which should be expected to increase (at least in proportional terms).

The available studies of the R&D dimension of the enterprise sector in Portugal are not many but all point in one way or another to a secondary position of R&D activities in strategic decision-making. The perspective is not homogeneous and varies across sectors.

It is interesting to compare two major survey exercises made with a time lapse of approximately five years. Although they give us only snapshot views, one can compare the evolution of the perspectives relative to innovation. One of the surveys (GEPIE, 1992) was made during 1988-1990 and it consisted of a postal questionnaire sent to 3276 enterprises with a response rate of 31,3% (1026 responses). The second survey

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[6] The activities of PNP institutions can also be classified under the term “Other Scientific and Technical Activities” which according to a study of its activities (Commission of the European Communities, 1991) may represent a large proportion of its activities; we are however more concerned with R&D activities proper when making the present considerations.

(Baranano, 1995) covers the period 1994-1995 and it was also a postal questionnaire sent to 12828 enterprises with a response rate of 5.08% (652 responses).

Table 45. Recent evolution of R&D expense in the enterprise sector.

	BERD Esc. Million (constant 1990 prices)	a.a.g.r. *	Personnel (FTE)	a.a.g.r. *	Researchers (FTE)	a.a.g.r. *
1988	9246,5		2041,8		473,5	
1990	13585,6	21,2%	1996,6	-1,1%	436,6	-4,0%
1992	13466,2	-0,4%	1881,7	-2,9%	481	5,0%
1995	11921,1	-4,0%	1768,3	-2,1%	463,7	-1,2%

Source: JNICT and OCT.

* a.a.g.r.=average annual growth rate

Although the questionnaires are not similar and have different objectives and questions and it is somewhat difficult to make a direct comparison of both, there are however some questions where one can venture to make a direct comparison. For instance, in the 1992 questionnaire there was a set of questions related to the factors of innovation. The question asked the respondent to indicate in a given list of factors, by order of importance, those that had the biggest impact in terms of product, process or management innovation. At the top of the list came the acquisition of equipment and at the bottom came investment in R&D activities. In the 1995 questionnaire there is a similar question, i.e., the firms are asked to indicate (in this case to attribute a score, on a 1-10 scale) which, of a given list of factors, are the most important determinants for success in innovation. The most striking similarity is the position occupied by investment in R&D activities, which came again at the bottom of the list (this time the second least important factor). Another similarity that stands out is the importance given to two factors: attention to customer needs and the improvement of products. Acquisition of equipment is also given prominence but only when it refers to product innovation (a distinction that was not made in the first survey). So, essentially the strategy of Portuguese firms as a whole continues not to be based on investment in research and technological activities but rather on the satisfaction of specific customer needs (one of which perhaps is the cost factor) and in what is now called “creative imitation” (competitors’ products and their analysis are the 2nd most important source of product innovation according to the 1995 survey) and in the introduction of new equipment and emphasis on production factors. The numbers on GERD given above confirm the continuation of this strategic perspective.

However, there are some improvements relative to the late 1980s. The responses of the 1995 survey seem to indicate that the industrialists begin to give more importance to intangibles and particularly those related to management innovation.

The 1992 survey asked which of a given list of management practices had been introduced. The main practice (the practice most often mentioned by the respondents) was the “introduction of computer aids to management”. However, the term management was very vague and ill defined. Based on the few empirical studies of the time (Kovács, 1990), it is believed that most of that activity is related to the automation of office and administrative tasks (and even so, partial automation) and not the automation of production (with the introduction of systems such as CAD, CAM or CIM). According to this author, advanced automation was used by a relatively minor percentage of the firms (18%), and most of them related to the use of CAD only and isolated CNC production equipment. Management seems to be conducted within “Taylorist” lines and worker participation seems to be reduced. In the 1995 survey the respondents scored high training and cultural factors. For instance the following factors were classified in the top positions as the most important factors for success in innovation (out of a given list of factors): “to develop a culture of continuous improvement”, “general improvement of personnel qualifications” (training factors are also important in the 1992 survey), “to develop team spirit”, “to improve the capability to adapt to change” and “more efforts to reach a common company vision”.

We should note again that comparisons should be viewed with care because the absence or presence of questions in the questionnaires makes absolute comparisons between the two surveys difficult. However, what seems to stand out is that the basic strategy followed by Portuguese firms remain basically the same: low investment in R&D activities, product innovation based on adaptation and improvement of existing products or technologies, emphasis on process innovation based on the acquisition of machinery, slow introduction of automated equipment and reduced integration with other activities of the firm.

The industrial sector has benefited since 1988 from major development programmes (see p. 139) namely the PEDIP (Specific Programme for the Development of Portuguese Industry) which was in effect from 1988 to 1992 (it was created in 1988 and formulated during that year by several laws and legislative acts; see Ministério da Indústria e Energia, 1993) financed partly (the largest part) by structural funds of the EU and by the government. Table 46 details the investment covered by the EU and the government, which, depending on the programme, should involve also private investment. The most important axes of intervention with implication for the research system were: 1) the support for technological infrastructures; it contributed substantially to the creation of a considerable number of institutions (envisioned but not substantiated by early plans) concerned with technical and other support activities directly linked with the needs of industry and the creation of institutions in the interface between academia and industry or concerned with diffusion of technical change and the support of entrepreneurial activities based on technological factors (see detail in Table 46); 2) a second axis was concerned with professional training, particularly those at advanced level and aimed at training researchers for industry; 3) a third axis was concerned with productive investment, i.e., innovation by means of acquisition of modern production equipment. Support for R&D projects was a diminutive part of this programme.

Table 46. PEDIP: Specific Programme for the Development of Portuguese Industry, 1988-1992.

Programmes	ECU million	% of total
Total PEDIP:	**1622**	
1. Basic and Technological infrastructures	**528**	**32,5%**
1.1 Basic infrastructures (energy, roads, railways, ports)	276	17,0%
1.2 Technological infrastructures (metrological laboratories, Sectoral technological centres, institutes for diffusion of new technologies, centres for technological transfer, Technological poles, enterprise incubators)	251	15,5%
2. Vocational Training	**185**	**11,4%**
Vocational training, training of instructors, Specialists and technicians; production and development of advanced pedagogical methods; management courses; training of researchers for industry; reinforcement of links between continuous training and enterprises		
3. Incentives for productive investment	**666**	**41,1%**
3.1 PEDIP system of incentives (SINPEDIP)	573	35,3%
3.2 Rationalisation of energy consumption (SIURE)	15	0,9%
3.3 Restructure and modernisation of industrial sectors		
3.3.1 Restructure and modernisation of the woollens sector	24	1,5%
3.3.2 Restructure and modernisation of the foundry sector	34	2,1%
3.4 Support for specific industrial sectors		
3.4.1 Integrated programme for Information Technologies and Electronics (PITIE)	16	1,0%
3.4.2 Programme for the Development of the equipment goods industry (PRODIBE)	5	0,3%
4. Financial engineering	**43**	**2,7%**
Financial aid for investment projects, enterprises in difficulty and Capitalisation of enterprises; creation of two risk capital enterprises (SULPEDIP and NORPEDIP).		
5. Productivity missions	**128**	**7,9%**
Activities aimed at improving the productivity of enterprises; Demonstration projects; support for Entrepreneurs; protection of intellectual property and inventions.		
6. Industrial Quality and design	**62**	**3,8%**
Development of standards, metrology and approval and certification methods; incentives to improve quality and design.		
7. Management of the Programme	**10**	**0,6%**

Source: Ministério da Indústria e Energia (1993).

It is difficult to evaluate the impact of the programme. It seems that its most important contributions are related to the technological infrastructures it created. As mentioned it contributed to the creation of nine sectoral technological centres[7], two technological parks, one innovation agency and several institutes in the interface between academia and industry. An important contribution is also the one devoted to the development of the so-called Portuguese System of Quality, concerned with certification, normalisation and standards. Several physical infrastructures were created or restructured and precise rules were defined and implemented concerning certification matters and the co-ordination of the several actors intervening in the system.

The central programme of PEDIP was the third one - Incentives for Productive Investment - and particularly the measure 3.1 (SINPEDIP), concerned with innovation, technology acquisition and the increase in productive capacity and modernisation of the production processes. A study made by the Ministry of Industry and Energy (Ministério da Indústria e Energia, 1994a) on the impacts of the programme seems to conclude that globally the programme was beneficial to Portuguese industry and it did strengthen existing industrial clusters in the main industrial districts (Lisbon, Porto, Aveiro, Braga) but there was apparently too much emphasis on capacity expansion and not enough emphasis on modernisation and innovation (p.32-33), which eventually later created complications when the recession came in 1991-1992. Many firms were caught off-guard with too much installed capacity and debt to resist an unexpected cut in demand. The study seems encouraged with the potential for structural change that some indicators seem to suggest, such as the presence of many small firms in all sub-programmes and the large percentage of the total population of firms above a certain dimension (100 employees) which were supported. This last view is supported by Confraria (1995).

The second edition of this programme was called PEDIP II (Strategic Programme for Promoting and Modernising Portuguese Industry) and it is a 2.2 ECU billion programme that will run from 1994 to 1999 (Table 47). The main axes of intervention remain essentially the same: incentive for productive investment (sub-programme 3 with 50.9% of total incentives), technological infrastructures (sub-programme 1 with 16% of total incentives) and professional training (sub-programme 5 with 14.1% of total incentives) but there was a substantial effort to integrate all the sub-programmes of the PEDIP II (a criticism often made of PEDIP I was the lack of logic and co-ordination between the sub-programmes). To achieve greater co-ordination and integration the sub-programmes are linked by an incentives system which is the operational rational of the programme. The implementation of the several sub-programmes is made by a set of five Incentive Systems that are grouped together according to the type of beneficiary. Additionally, each system is composed of a set of support Regimes that group measures or sets of similar measures and are managed by only one entity of the Ministry. The five Incentive Systems are:

- SINFRAPEDIP: support of technological infrastructures and the System of Industrial Quality;
- SINETPEDIP: consolidation of technological professional schools;
- SINFEPEDIP: financial engineering to support enterprises;
- SINAIPEDIP: consolidation of industrial support services;
- SINDEPEDIP: incentives for production investment.

The relations of these incentive systems with the sub-programmes are indicated in Table 47. There was also an increased preoccupation with ex-ante evaluation of the candidates to avoid the common situation that happened during PEDIP on which the firms were incapable of sustaining the investment they asked for.

[7] The technological centres were created in the more traditional industrial sectors. They include: textiles, ceramics and glass, cork, wood and furniture, shoemaking, leather, decorative rocks, mechanics, and moulds and special tools.

Table 47. PEDIP II: Strategic Programme for Promoting and Modernising Portuguese Industry, 1994-1999.

Sub-Programmes	ECU million	% of total	SINFRAPEDIP	SINAIPEDIP	SINETPEDIP	SINFEPEDIP	SINDEPEDIP	Voluntary actions	Programme management
Total PEDIP II:	2214,8								
1. Support and Consolidation of Technological infrastructures	**353,4**	**16,0%**							
1.1 New infrastructures for industry	155	7,0%						1.1	
1.2 Support for existing technological infrastructures	84,9	3,8%	1.2						
1.3 Support for existing quality infrastructures	8	0,4%	1.3						
1.4 Support for existing associative infrastructures	23,7	1,1%		1.4					
1.5 Support for existing professional schools	4,8	0,2%			1.5				
1.6 Other support services	34,4	1,6%		1.6					
1.7 Transfers from previous PEDIP	42,6	1,9%							
2. Complementary mechanisms of financial engineering	**225,2**	**10,2%**							
2.1 Risk capital societies	109,5	4,9%				2.1			
2.2 Financial support for investment	55,1	2,5%				2.2			
2.3 Support for mutual societies	46,8	2,1%				2.3			
2.4 Support for investment funds	13,8	0,6%				2.4			
3. Consolidation and reinforcement of enterprises strategies	**1127,8**	**50,9%**							
3.1 Audits	30,6	1,4%					3.1		
3.2 Technology acquisition and development	64,3	2,9%					3.2		
3.3 Innovation and internationalisation	328,1	14,8%					3.3		
3.4 Support of dynamic factors of competitiveness	68,9	3,1%					3.4		
3.5 Small modernisation projects	25,2	1,1%					3.5		
3.6 Strategic contract-based programmes	226,5	10,2%					3.6		
3.7 Certification, standards	6,2	0,3%					3.7		
3.8 Industrial property	6,9	0,3%					3.8		
3.9 Support for accession to the stock market	4,6	0,2%					3.9		
3.10 Transfers from previous PEDIP	366,5	16,5%							
4. Productivity, quality and internationalisation promotion	**139,4**	**6,3%**							
4.1 Quality and design	18,4	0,8%						4.1	
4.2 Inter-firm co-operation	8,9	0,4%					4.2	4.2	
4.3 Internationalisation	6	0,3%						4.3	
4.4 Innovation and technology transfer	35,6	1,6%						4.4	
4.5 Environment	5,8	0,3%						4.5	
4.6 Productivity and demonstration projects	12,7	0,6%					4.6		
4.7 Technological infrastructures close to industry	38,6	1,7%						4.7	
4.8 Specialisation strategies and organisational change	2,8	0,1%						4.8	
4.9 Energy efficiency	10,6	0,5%						4.9	
5. Human resources promotion	**313,3**	**14,1%**							
5.1 Vocational training under goals of Programme 1	22,9	1,0%	5.1	5.1	5.1				
5.2 Vocational training (goals of Programmes 3, 4)	139,6	6,3%					5.2		
5.3 Support of specific measures	117,7	5,3%						5.3	
5.4 Technical support for professional training	6,3	0,3%							
5.5 Transfers from previous PEDIP	26,8	1,2%							
6. Management of the Programme	**55,7**	**2,5%**							6

Source: Ministério da Indústria e Energia (1994b). Note: these numbers are projections and may not correspond exactly to the execution of the programme.

The evaluation is also made having in mind the confrontation of the real needs of the firm and its actual demands. It is a precautionary measure to optimise the incentive.The incentive is not exclusively or predominantly directed to modernisation or expansion of capacity but it can encompass several dimensions according to the specific situation and circumstances.

Another change relative to PEDIP is that now many of the incentives are not non-refundable subsidies but rather loans at zero interest rates (apart from the fact that only part of the investment is financed, as with PEDIP, the so-called “matching” system). The aim is also to send a signal of caution to the potential candidates. Two sectoral programmes for electronics, information technologies and equipment goods, in line with PEDIP’s previous PITIE and PRODIBE were launched (PRATIC substitutes PITIE and PRODIBETA substitutes PRODIBE). There is also an increased concern in terms of integration with other major programmes, namely with PRAXIS XXI, when it concerns R&D activities. Unlike the first editions of the programmes, these ones benefited from accumulated experience and from the fact that the negotiation with the European Commission for the 2nd Framework Programme for Portugal was over an integrated packet (Secretaria de Estado do Plano e Desenvolvimento Regional/Ministério do Planeamento e Administração do Território, 1994). All the major programmes were included in an integrated manner on that packet (cf. section on the economic system and Table 26 on that section).

PEDIP II is now at “cruise” speed and it is premature to advance any conclusions. The available indicators (INFOPEDIP, several issues) seem to indicate a good adherence to the programme in sub-programmes related to productive investment (in general, sub-programme 3) and particularly to the sub-programme related to quality certification (sub-programme 4). This pattern seems to suggest a continuation of the central strategy of Portuguese industry relative to innovation, that is, improvement of existing technologies, be it product or process, and a relative disregard for R&D proper. The importance attributed to quality issues was considerable and it is reflected by the growing number of

ISO certified enterprises, which have grown at an annual average growth rate of 100% between 1991 and 1996 (IPQ, 1997).

7.13 The research system: a summary

The research system evolution was inextricably linked to the educational system, dominated by the same scholastic influences and by the same structural deficiencies pointed earlier. The situation only begins to changes (modestly) by the end of the 1800s and early 1900s.

Important quantitative and qualitative changes occur only after the 2nd World War, in connection with a phase of high growth rates of the Portuguese economy. R&TD and “Other Scientific and Technological” activities are done mainly in the newly created state research laboratories and are directly linked to scientific, technological and technical needs of infrastructure development. Research funds for universities were very diminutive. Only when the educational system was restructured in the early 1970s did university research increase in importance and volume, a trend that will only be perfectly visible in the early 1980s. R&D resource allocation is now more or less evenly spread between the two sectors. It seems that the dual character of Portuguese society reveals itself again in this competition for funds between the state research laboratories and the universities.

Research in industry remained diminutive and proportionately is a small part of GERD. The technology balance of payments was negative and resources spent in industrial R&D were limited and low by OECD standards. The situation remains much the same nowadays.

Resource allocation is not evenly distributed compared to the distribution of population. R&D resources are heavily concentrated in the capital city area, particularly the resources allocated to the state research laboratories which are the main vehicles for technology transfer and diffusion to industry. In spite of recent institutional attempts to increase relationships between the research laboratories, the universities and the enterprises, the most notable result of which is the proliferation of PNP institutions, there is no visible significant increase in the flow of information between the sectors nor there is no visible change in industry perception of the strategic importance of R&D activities.

Overall, indicators of R&D inputs (expenses in R&D or personnel allocated to R&D) and of R&D outputs (patents) are still considerably lower than OECD average. The considerations about the education system made in preceding chapters are also applicable to the research system in particular those that refer to the impact of the dualistic character of the educational system (existence of weaknesses in skills at the medium level) on the supply of labour for the industrial sector. Other problems are related to rigidities, namely to difficulties in communication flows between the sub-systems with potentially important impacts in terms of diffusion of knowledge, technology and skills, and problems in terms of diversity, namely the deeply ingrained intellectual aversion to (constructive) criticism and to the creation of alternatives schools of thought, particularly when it involves new scientific areas and multidisciplinary approaches.

In spite of efforts at the policy level to implement an integrated approach to science and technology, there has been an inability to effectively link science policies and the institutions that implement them (JNICT and now the Ministry of Science and Technology) and technology policies and the institutions that implement them (e.g. sectoral Ministries).

The impact of all these characteristics on the industrial fabric of the country is, on the one hand, a generalised shortage of supply of skilled labour and on the other hand, the absence of adequate conditions to stimulate an environment conducive to creative thinking and innovative behaviour.

CHAPTER 8. EXPLAINING THE SYSTEM LEVEL: FINAL REMARKS

What seems to stand out from the previous analysis of the innovation system in Portugal is the immense and primary impact that the underdevelopment of the education sub-system had on the other sub-systems an on the system as a whole. The shortcoming of the education system became particularly negative after the Renaissance. On one hand, the system did not grow enough. The reason why it did not is probably connected to political reasons (the reverse reasons that underlie other Western European countries' earlier universal education). Reis (1993) argues that Portugal, unlike other more volatile states, was a state where there was only one Nation and one language and consequently there was no need to introduce any special education effort as a way to forge or reinforce national unity. Nor there was an internal threat to national independence and unity from any specific regional ethnic or non-ethnic group. The cohesion of the county was also reinforced by long-established borders dating from the 12th and 13th centuries and facilitated by the fact that the borders were with only one country, namely Spain. On the other hand, the education system did not adapt itself properly or in a timely manner to the new intellectual era and trends related to the scientific and technological disciplines. It persisted in its traditional emphasis on humanistic and literally studies, itself a consequence of the heavy presence and tradition of scholastic schools within the system.

The features of the education system are certainly intimately connected to the broad political-ideological environment. Portugal has a political ideological history of its own that distinguishes it from other European countries, particularly from those of the northern part of Europe. Although geographically a part of Europe, Portugal has been culturally and politically often considered apart from it. The ideology that prevailed in Portugal, whose roots can be tracked down from almost its inception in the 12th century as a distinct, unified country state, is strongly connected to corporatist ideas. Portugal shares its corporatist tradition with Spain and almost if not all, Latin-American countries, although, of course each country has its own distinctive and unique features. The corporatist mechanism is marked by a strong centralising tendency that gives the state predominance in the process of socio economic decision making. The main actors in the political process of decision making are the state and a series of broad social groups with vested interests in the human, natural and capital resources of the country, like the church and the nobility in ancient times, and more recently, the commercial and industrial monopolies which arouse due to political, social and economic transformations. What basically distinguishes it from the liberal northern European political tradition is the relative absence of pressure groups born from the roots of the country's population. The relationships between the social classes are more accurately described by a model of patronage-clientelage than by a model of representative-constituent, which partly explains why a sharp distinction and divide between social classes tenaciously remained. Only in recent decades did Portugal embrace more decisively the liberal tradition that has been prevalent for centuries in northern Europe countries, establishing a more representative mould of political institutions. The corporatist legacy is, however, still deeply rooted in the ways those institutions operate. It was also in recent years that special attention was given to the education system but the tradition impinges on the institutions and on the capacity of critique, on diversity and on innovative behaviour. These restrictions have special negative consequences at the level of the research system affecting one of its main characteristics, which is its capacity to create and accommodate and explore diversity (Metcalfe, 1993). Typically, intellectual confrontation between different research schools is very difficult or non-existent. It tends to be based on destructive criticism rather than on constructive criticism and usually there is an overriding prevalence of one school of thought with total or almost complete elimination of the other schools. One may question if the small size of the research system is a cause or a consequence of this attitude. Nowadays, the main institutions that perform research in Portugal are handicapped by this function. The universities have not a research tradition, for the reasons exposed above and in previous chapters, and their main function is teaching. The state research laboratories display probably too much of an ostentatious term (research) when referring to themselves. Their genesis, explained previously, ascribes to them a strong component of providers of technical services aside from their research functions, which are, by the way, essentially at the applied or development level and thus with limited possibilities in terms of the advancement of pure knowledge. In any case, the links between the two kinds of institutions seem to be rather weak.

Links between the industrial sector and the research system are also weak. There is eventually a causal relationship between the technological demand level from firms and the slow evolution of the education or research system, and the low level of technological supply from industry, in the sense that the Porter-like demand structure of the country is not demanding enough nor there are dense relationships between the firms.

The impact of the corporatist ideology on the macro-economic system of the country has been that of creating a capitalist system dominated by a monopolistic, mercantilistic and state controlled structure, and still particularly prevailing within those industrial sectors actively supported by the government for strategic reasons (since the mid 1940s). On the other hand, the more traditional industrial sectors, with a much lower concentration ratio, with an industrial structure characterised by a large variety of firm sizes, has a much stronger Schumpeterian spirit, marked for its entrepeneurship vigour and free-lancing attitude. The state-supported large industrial firms and sectors (steel, petrochemicals, shipbuilding, heavy machinery) are mainly concentrated in the centre of the country, particularly around or close to the Lisbon area (not coincidentally they are near the centralised locus of the main political decision making), and have more or less been in a state of permanent crisis since the early 1970s. The traditional, free market oriented firms and sectors (textiles, shoe making, foodstuff) are concentrated mainly in the north, near or close to the city of Porto and have proved much more adaptable to external changing conditions, and are still continuing to contribute to a large share of total industrial output. Of course, this is an extreme picture and an over simplification of the reality, but it has some substance. To complete this simplified picture, there is a range of other geographically dispersed firms and sectors that are markedly Schumpeterian in nature, such as subsidiaries of multinationals in the electric/electronic industry, in the car industry and machinery industry. Their Portuguese counterparts and competitors are less aggressive in terms of dynamic adaptation, as well as those more traditional metal industries, wood and wood products, ceramics and glass that fall between the two extremes of entrepreneurial spirit and patronage-clientele approach.

Overall Portuguese firms have been and are still marked by an excessive neo-classical rational behaviour in the sense that they tend to allocate their resources in a short-term perspective. Thus the system suffers from classic Schumpeterian static inefficiencies as opposed to long-term dynamic efficiencies in the allocation of resources. Such behaviour would explain why industry is less prone to invest in activities not seen to provide visible short-term advantages. In that light certain facts can be explained: the small size and the weak power of industrial associations; the long-term conflicts between rival industrial associations; weak linkages between equipment producers and users; low importance ascribed to education and training with reflections on all areas of industrial activity, including technological, commercial and management level; weak demand for technology, either in the form of services or in the form of research or development and the consequent weak linkages between the industrial sector and the research and education sector.

Two important examples can be pointed out. On the one hand, the excessive emphasis on production strategy given by Portuguese firms and the relative disregard for management issues shows a lack of a comprehensive strategic approach to technology according to Simões (1994) that identifies some of the issues in the following way:

> “The critical problems regarding innovative efficiency of Portuguese manufacturing enterprises may be clustered around half-a-dozen closely inter-related axes: weakness in strategic thinking; insufficient concern with the "soft", intangibles aspects which are at the hearth of innovation (organisation, tacit knowledge, information, quality); insufficient focus on marketing; paucity of "in-house" technical skills; scarce backward and forward balanced and demanding linkages; and scarce use of the national network of technical support services" (p.15).

On the other hand, the development of industrial technological capability has very much relied on the imports of technology developed elsewhere. It carries with it two kinds of interconnected dependency. The first is a direct dependency expressed through the very act of purchasing a particular technology. The second, an indirect dependency arising from operational necessities of equipment maintenance, equipment modifications and specific tacit knowledge which can only be efficiently tackled by those who provided the technology in the first place. Thus, two immediate impacts of the behaviour are 1) weaknesses in the ability to exert technological demand pressures on domestic firms to supply equipment, machinery or technology in the broadest sense, and 2) weaknesses in the ability to enhance inter-sectoral domestic contacts and relationships between the industrial sector and the system providing technological services. One can say that the justification for these behaviours is, in the first place, the absence of domestic capability to provide such technology, but the concern is not so much with the initiation of the process but with its continuation. Apparently the Portuguese industrialists have so far managed relatively well, and are not inclined to change tactics, unlike the Asian NICs for whom the import of foreign technology is but one input to a broader strategy of technological development with wide diffusion impacts throughout the whole economy. The recent downward trend in business R&D expenditure share can be tentatively explained as signalling yet another new cycle of technological dependency through the acquisition of new vintages and the discontinuation of indigenous adaptive R&D efforts on old vintages. The new theories of intra-firm trade and recent data showing increasing shares of multinational firm's in Portugal exports (Simões, 1993), may also add another explanatory factor. Tentatively again, there is a suggestion that subsidiaries of multinational firms do not have anymore to sustain divisional R&D departments whose adaptive R&D function is no longer needed.

So far, in this synopsis of the evolutionary dynamics of the Portuguese innovation system, the factors pointed out have been mostly by the negative side. However one must not mask the other side. It should be emphasised that in spite of all the mentioned shortcomings and gaps the system managed to build a considerable and by no means negligible technological capability. At least it has not allowed that the income and technological gap (which worsened during the 1800s; cf. previous chapters) between Portugal and other Western European countries grew larger. The causes of such gaps were and are a constant national preoccupation and are at the origin of constant, persistent but not very articulated efforts to bridge those gaps. Those efforts and their real performance have increased substantially after 2nd World War giving way to huge changes and progress. However, the gap remains unclosed.

To conclude it should be remembered that the above exposition was an attempt to characterise and define the past and present environment surrounding Portuguese firms, and how likely they have impacted or do impact on the indigenous innovative and R&D capabilities and activities of those firms. By what has been written one can expect that the system is characterised by the following distribution pattern of firm innovative behaviour: a small number of very traditional firms, a large proportion of firms employing below average product and process technology and a growing but minority proportion of firms employing average process and product technology. Only a very small number of firms will employ above average process and product technology, partially internally developed, and with a competitive position in international markets. Absolutely original, advanced, state of the art innovative output will probably be non-existent or at best extremely rare.

PART III. EXPLAINING FIRM LEVEL VARIATION

CHAPTER 9. INTRODUCTION

This part of the study is concerned with the behavioural causes of innovative performance at the firm level. The quest for the determinants of innovation at the micro level has received increased attention in the social and economic sciences. The interest in this issue follows from the realisation that the efficiency of inputs to scientific and technological activities, as measured by the correlation between R&D expenditures and GDP growth rates, enjoyed significant discrepancies across a whole series of countries. The Japanese technological performance recently reinvigorated this debate and provoked a frenzied search for the explanations of this phenomenon, not only at the macro level (e.g. Freeman, 1987) but also at the micro level (e.g. Womack, J.P. et al, 1990).

The first instances on this quest may be traced back to Marx who saw the continuous stream of technical innovations as being directly related to the selfish pursuit of rent-seeking activities by the capitalist pole of the dual-class society which he portrayed. The invention of new machines and tools that increased the level of mechanisation of the production process and that decreased the individual or collective power of the operators, and hence allowed for the appropriation of labour surplus by capital, were the main goal behind the innovation process. The relentless pursuit of ever larger profits earned by the capitalist at the expense of the worker, the exploratory attitude of the entrepreneur and his disregard for his employees and fellow man, were implicitly the behavioural attributes that characterised a technologically successful entrepreneur. Earlier, Adam Smith also hinted at a similar kind of motive when he analysed the economies gained by increased specialisation, but the hints stop short of that and no significant attempts were made to distinguish the features of innovative firms.

The orthodox neo-classical school of economics dismissed the subject all together. Firms were viewed as homogeneous, perfectly informed, rationally acting black boxes, whose only admissible difference was a short lagging period necessary to adjust themselves to the price signals of the market. Knowledge, science and technology were assumed to be non-excludable, non-rivalrous public goods, exogeneously determined and at the disposal of all firms and with no extra costs attached. Even the notion of profit is not useful in the neo-classical context as an explanation of why firms innovate, given the constrains imposed by the assumptions underlying marginal analysis, and some authors go even further when assessing this theoretical framework:

> "...Indeed, under the standard assumptions [of the neo-classical theory] it is difficult to find reasons why firms exist at all..." (Reinert, 1995, p. 27)

However, to be fair, the neo-classical economic tradition has made significant contributions over the last decades to the understanding of technological progress and its interactions with market mechanisms. Technical change was identified as a main determinant of economic growth (Solow, 1956) and technological knowledge was incorporated in the aggregate production function as an endogenous production factor. Differences in factor-price ratios are pointed to as a main endogenous determinant of bias in the choice of technique, and the notion of induced innovation is introduced. Schmookler (1966) ignited the famous debate opposing the demand-pull and the technology-push hypotheses of technological change, by emphasising that demand factors could explain to a large extent the rate and direction of technological change. His study was partly a response to the argument advanced by earlier studies of Schumpeter that inventors-entrepreneurs were the main forces behind technical change and growth. The notion of learning by doing and its economic implications was first introduced within a neo-classical context (Arrow, 1962). The existence of increasing returns to scale in the aggregate production function is explained in terms of externalities derived from the development of technical knowledge.

However, since these studies were conducted within the same basic assumptions of the orthodox neo-classical school, namely the notion of equilibrium, the rational behaviour of firms and the assumption of perfect information, their explanatory contribution is more at the macro-economic level than at the level of the firm, and their contribution was stronger to market theories than to the theory of the firm. The theoretical framework could not satisfactorily explain why some firms are more innovative than others and why there seems to exist, at any time, and given the same environment, a population distribution pattern that includes both firms using advanced production techniques and firms using older techniques.

Contributions to resolve this lack of theoretical support of empirical facts came initially from the management and organisation literature, which identified differences in the inner workings of the firms and then tried to identify the factors behind those differences. One group of studies, following from Marris (1966), highlights the importance of managerial motivation and discusses it in terms of sociological and psychological traits, such as status, power, space for personal creativity and remuneration (which is a more classic perspective). Another theoretical line comes from the work of Penrose (1980), suggesting that the firm is a bundle of physical and human resources and its evolution is fundamentally determined by its managerial capabilities.

Other approaches focus on the structural characteristics of the firm. The transaction-costs approach (Williamson, 1981), which was inspired by Coase's (1937) account of the firm as a governance structure, deals with the costs associated with performing certain types of economic activities and their influence on the structure and size of the firm. He argues that certain inherent characteristics of some economic exchanges, namely those connected to imperfect markets, uncertainty, and opportunistic behaviour, make it more economical for the firm if those transactions are internalised inside the hierarchical structure rather than making them in the market. The behavioural perspective of Cyert and March (1963) emphasises the conflicts that arise from the fact that the firm pursues different goals at the same time, associated with production, inventory, market, sales and profit. For instance, higher sales may imply lower profits, higher production may imply higher inventory costs. The firm is then seen as the (unpredictable) outcome of complex internal negotiations and compromises that try to achieve a degree of consistency between diverse goals.

Explicit technological considerations are more visible in the organisational models of Woodward (1965), and Mintzberg (1984). They combine several salient features of earlier approaches into an integrated framework, and then propose a taxonomy of organisations. Woodward's approach is more technologically determined while Mintzberg's is the outcome of complex interactions between internal factors as well as external ones. In both models, the organisational structures of firms are closely connected with technological factors such as the degree of complexity of the technology used by the firm or the characteristics of the production technology. They link innovative performance with organisational traits in a causal direction that seems to indicate that technology determines the type of organisational structure rather than the other way around.

A different theoretical perspective on the issue of different patterns of firm behaviour and their technological implications comes from the evolutionary theories of economic and technical change, which integrates insights from the management, organisation and economic literature. Their main source of inspiration is the work of Schumpeter (1939), which challenged the neo-classical tradition assumptions of equilibrium and perfect information. The concepts of disequilibrium and imperfect knowledge appropriability are at the core of the Schumpeterian analysis. The neo-Schumpeterian or evolutionary theories assume that the choice and actions of the firms are severely constrained by imperfect information. Their behaviour cannot be assumed as rational but rather as "boundedly" rational, i.e., limited by the kind and level of information that the economic agents possess at any given moment. Therefore, achieving a satisfying but not necessarily optimal condition is the norm, rather than achieving a maximised optimal situation (Simon, 1956).

Evolutionary theories are stranded in a psychological basis, inasmuch as they emphasise the learning processes involved in the economic process, and they are less amenable to formalisation. The behaviour of firms is dependent and shaped by:

> "...the learning history of agents, their pre-existing knowledge and, most likely, also their value systems and their prejudices..." (Dosi, 1994, p. 159)

The analogies with biological systems entails the definitions of four concrete building blocks (Dosi, 1994): 1) a fundamental unit of selection (genes), which could be technologies, policies, behavioural patterns or cultural traits; 2) a mechanism linking the genotype level with the entities (phenotypes), and these could include technological systems, firms, agencies or the mind; 3) mechanisms and criteria of selection, involving a long list of possibilities such as, for instance, financial market assessments of firms' strengths, characteristics of their products, their prices, etc.; and 4) mechanisms that generate variations (in the phenotypes through the genotypes), which is the dimension that is directly linked to the presumption of rational behaviour.

The link between the technological performance of a firm and its organisational and behavioural characteristics, which is the main concern of this section, is achieved in the evolutionary literature through the notion of routines. Nelson (1982) identifies three sets of routines: 1) standard operational routines, related to the way firms produce under certain constraints, namely their capital stock and their knowledge content; 2) routines that determine the investment behaviour of the firm; and 3) routines that define the process of search for doing better things.

Working, explicitly or not, within this framework of analysis, there have been several contributions to the understanding of the link between innovative performance and behavioural patterns of firms. Miles and Snow (1978) classify firms under the heads of "defenders", "prospectors", and "reactors". Freeman (1982) also proposes a taxonomy based on archetypes of strategy and classifies them under the groupings of "aggressive", "defensive", "imitator", "traditional" and "opportunistic”.

A series of empirical studies tried to identify the factors that led to success or failure in innovation in a specific product, of which the most well known are probably the Project SAPPHO (Rothwell et al, 1974) and the M.I.T. study (Utterback et al, 1975).

Rothwell (1977) makes a review of the results of seven of the more important studies and finds a considerable degree of agreement between them. The identified success factors are linked to good communications and effective collaboration, high levels of corporate commitment, planning and management techniques (with emphasis on cost control), quality of management, personal policy and management style (emphasis on education and training), marketing and user needs, and after sales and user education. Apparently, the two sets of factors more strongly correlated to success are related to communications and collaboration, and marketing and understanding of user needs. Thus, the findings seem to revive the demand-pull/technology-push debate, bending in favour of the demand-pull hypothesis. The author also argues that the innovation process is a complex one and all factors must be taken into account, but advances little in the way of explaining the interactions between them. Mowery and Rosenberg (1979) criticise the conclusion by arguing that there was a built-in bias on the studies. The criticisms addressed the fact that citing user needs ex post facto could be considered a tautology, that the concept "user needs" was loosely defined and it lacked the precision of the economic concept of demand, and that technology-push factors were not conveniently represented in the studies. It concluded that not only supply and demand factors are important factors but also they must be coupled to ensure success.

These studies contributed to the advancement of our understanding of the innovation process in several ways. They represent a significant challenge to established theories, they pinpointed some apparently recurrent behavioural factors in successful innovation, and they brought to the surface the systemic features of the process. They also stimulated further research at sectoral level. For instance, Pavitt (1994) builds on his earlier sectoral innovation taxonomy of industrial sectors (Pavitt, 1984) and suggests a technology-based classification of key characteristics of innovative firms.

This paper adopts a somewhat different approach. While most of the earlier studies concerned with success and failure concentrated their attention on particular innovations at a particular point in the life of the firm, the approach here is based on the difference between the global perception of the firm as, all things considered, being more innovative than the average and the perception of another firm as being only average or less than average in innovative terms. It can be argued that the study of only a single innovation, at a particular point in the life of the firm, does not tell us much about the firm as a whole and about the way it got where it is. As such, one can say that a static perspective considerably influences such studies. They also do not have much to say about the way in which the multiple factors interact with each other.

We should not forget that there are authors that follow a dynamic approach. Maidique and Zirger (1985) suggest that a more useful unit of analysis is the product family, rather than the single new product. They argue that organisations learn from their mistakes ("learning by failing" as they put it) and that a failure often may lead to a posteriori success. They suggest a new (family) product model, which has the attractive feature of being explicitly more dynamic, based on cyclical failures and successes of individual products, each success feeding on a previous failure and each success, in turn, eventually leading to a failure (due to excess confidence breed by the success). Georghiou et al. (1986) argue that the innovation process can only be correctly understood if the conditions and set-up at the time of launching an innovation and its posterior progress and diffusion are looked at simultaneously. For these authors a successful innovative firm is not solely classified by the successful market introduction of an innovation and the initial perceived innovative level. The subsequent actions of the firm are as vital to its success as it is the introduction of the innovation. Therefore the firm has to engage "…itself to a sequence of post-innovative improvements which are a necessary condition for it to retain and expand its market share." (p. 3). They further argue that technological innovation is an outcome of interactions between technological opportunities and market needs which itself evolve over time.

Here, somewhat in line with Georghiou et al, instead of looking at a particular product or family of products we look at the global performance of the firm over time, and we try to identify characteristics that are common to innovative firms and characteristics that are common to less innovative or non-innovative firms. First, these characteristics are identified, and then an effort is made to identify the way in which these factors contributed to the present situation of the firm, as well as the way in which those factors interacted so that they eventually led to superior performances. Throughout the following chapters the reader will notice a strong flavour of the influence of evolutionary theories of technical and economical change. This is true, inasmuch as use is made of the conceptual framework provided by the analogies with the biological sciences. In particular we associate the notion of genes or genotypes with the identified characteristics of the firm and we associate the phenotype with the global performance characteristics of the firm. First the number of phenotypes is reduced to only two kinds, the innovative firms and the average firms, but later we propose an enlargement based on a continuous spectrum of phenotypes. The main thrust of the study will be in the analysis of the mechanisms linking the genotype level with the phenotypic level and in the analysis of the mechanism generating variation in the genotypes. We also consider the third conceptual block (mentioned above), which is the selection mechanism and the selection dynamics, but less formal structure is given to the environmental variables, and the main concern is to try to explain differential behaviour assuming the same external constrains. Implicitly, the degree of innovativeness is considered the best measure of fitness, but, as was mentioned earlier, empirical evidence suggests that this is not always (or indeed, even remotely) true, and some remarks on the issue will be made.

CHAPTER 10. QUANTITATIVE ANALYSIS OF THE RESULTS

10.1 Introduction

We shall recall that the methodology followed in this study was based on a SAPPHO-like approach (cf. Chapter 2), whereby pairs of firms were matched according to criteria of product similarity and size, forming two groups, the so-called “innovative” group, grouping together firms that showed above average innovative performance and the so-called “average” group, grouping together firms that, compared with their respective pair, were less innovative. A total of nineteen firms were approached and extensively interviewed according to the guidelines of Annex B. The purpose of the exercise was to find out if there were behavioural differences between the two groups of firms, identify those differences and explain them.

10.2 Identification and categorisation of differential factors

The information gathered through the interviews was submitted to statistical analytical procedures. Due to the limitations inherent in the sample, specifically its small size and its non-randomness, the analysis was confined to the application of descriptive analysis, to see whether differences in the distribution of the responses of the two groups could be visibly identified. The raw information was coded in nominal or ordinal categories, although for some variables the initial information was at the arithmetic level (continuous). However due to sampling restrictions, it was transformed into a lower level of measurement. In the end the analysis identified differences in the distributions. Table 48 shows the results, representing the variables that showed visible differences between the two groups of firms. The reader is referred to Chapter 2 for a detailed explanation of how the variables in Table 48 came about.

Table 48. Identified relevant variables and their definition.

Category	Variable	Definition	Categories values
Tangibles	Existence of automated equipment	The firm uses automated equipment.	Values: 1=yes ; 0=no
	Predominance of old production machinery	Share of manual production machines relative to total number of production machines.	Values: 1=yes (50% or more of manual machines); 0=no (50% or less of manual machines)
	Improvements in production machinery	The firm improved in-house its production machinery.	Values: 1=yes ; 0=no
Intangibles	Use of CAD	The firm uses on a routine basis CAD techniques.	Values: 1=yes ; 0=no
	Use of CAM	The firms uses on a routine basis CAM techniques.	Values: 1=yes ; 0=no
	Internal quality control laboratory	The firm has an internal quality control laboratory and makes internal control of quality of its products.	Values: 1=yes ; 0=no
	Existence of graduate personnel	There has at least one employee who possesses university level qualifications.	Values: 1=yes ; 0=no
	Graduate intensity	Ratio of graduate personnel to total employment.	Continuous variable.
	Type of training	Training procedures followed routinely by the firm.	Values: 2=training plan (involving all levels of personnel); 1=sporadic external short courses (mostly technical courses for the factory workers); 0=only internal (on the job)
	Separate R&D department	The firm has a separate department where personnel are allocated full-time to the design, development or research of new products.	Values: 1=yes ; 0=no
Management	Main source of funds for investment	Origin of funds for investment projects.	Values: 1=loans (more than 50% of funds are borrowed); 0=own funds (50% or more are firm's own funds)
	Receiver of subsidies	The firm has applied to and was awarded with state subsidies in the last five years.	Values: 1=yes ; 0=no
	Type of strategy	Planning procedures followed routinely by the firm.	Values: 3=long-term and medium-term formal planning; 2=medium-term formal planning; 1=visionary (unwritten medium-term plan) 0=short-term (planning is done on a daily basis)
	Approach to product conception	The way firms face their task of building machines.	Values: 1=integrated approach (system); 0=individual machine

Table 48. (Cont.)

Category	Variable	Definition	Categories values
External Stimuli	Existence of exports	The firm exports its products.	Values: 1=yes ; 0=no
	Export intensity	Percentage of production exported (in terms of sales).	Continuous variable.
	Importance of external competition	Scoring attributed by the firm to the importance of competition with foreign products as a stimulus to the development of new products.	Values: 5=crucial; 4=very significant; 3=moderately Significant; 2=slightly significant; 1=insignificant
	Type of domestic customer	Types of clients the firm predominantly deals with.	Values: 2=large innovative firms; 1=any domestic firm; 0=only regional firms
	Competition based on quality and performance	Scoring attributed by the firm to the importance of competition based on quality and performance as a stimulus to the development of new products.	Values: 5=crucial; 4=very significant; 3=moderately significant; 2=slightly significant; 1=insignificant
External sources of knowledge	Impact of fairs on future innovations	Scoring attributed by the firm to the impact of trade fairs on future innovations of the firm.	Values: 5=crucial; 4=very significant; 3=moderately significant; 2=slightly significant; 1=insignificant
	Impact on scrutiny by suppliers	Scoring attributed by the firm to the impact or usefulness of suppliers on search activities of the firm.	Values: 5=crucial; 4=very significant; 3=moderately significant; 2=slightly significant; 1=insignificant
	Impact on scrutiny by universities	Scoring attributed by the firm to the impact or usefulness of universities on search activities of the firm.	Values: 5=crucial; 4=very significant; 3=moderately significant; 2=slightly significant; 1=insignificant

The variables are categorised according to the nature of the factor involved. A set of variables is related to differences in the type of capital stock between the two groups of firms. They are categorised under the term "tangibles". The second set of variables is related to what is now commonly referred to as "intangibles" and the category in which they are included is named accordingly. They include the role of software, the level of education, the type of training and the existence of separate R&D departments and quality control laboratories. The third set of variables is related to management issues, and it reveals behavioural differences in areas linked to procurement of funds for investment, the type of strategy adopted and the approach to product conception. A fourth set of variables deals with what we call external stimulus to innovation and reveal differences on whether the firm had an export activity, to what type of domestic customer it was related, the degree of importance attached to external competition, i.e., competition in external markets or with incoming external products, and the degree of importance attached to competition based on quality and performance. Finally, the fifth set unveils some differences on the way external sources of knowledge impact upon the firm's innovation activities. Annex C gives the complete information on the responses given by each group to each variable in numerical as well as in graphical form. The meaning of each variable is described in Table 48. Tables and Graphics on Annex C are based on this nomenclature.

10.3 Demand factors

The results show obvious similarities with those obtained by the successful/unsuccessful empirical studies briefly reviewed in a preceding section. All the factors categorised under the term "external stimulus" are somewhat equivalent to the "marketing and user needs" factors suggested by those studies. If we consider these variables as proxies for the existence of demand for certain products, or product features, or as proxies for a response to "needs" (whatever the definition of the term) felt by consumers, then the results support the arguments expressed by the demand-pull theorists. The fact that export behaviour differs significantly amongst the "innovative" and the "average" group (see Table 49 showing the descriptive statistics of the continuos variable “export intensity”), and that the importance attached to external competition is more strongly felt by the former group, can be interpreted as innovative firms being more responsive to user demands, in the sense that we assume external markets are more demanding than the average internal market.

Table 49. Descriptive statistics of the variable “export intensity”.

	N	Minimum	Maximum	Mean	Std. Deviation
Average group	9	0	0.25	0.056	0.0982
Innovative group	10	0.05	0.85	0.35	0.2877

We make this assumption because roughly 90% of the exports are destined to the European Union countries, the United States, Canada and the Asian NICs. If, in principle, the demands from these markets are more commanding and require higher standards than those demanded by the internal average market, and assuming that products whose technological characteristics satisfying the internal average market would not satisfy the external markets, then demand (in its precise meaning involving quantities and prices) does apparently play a role in fostering innovation. The same argument applies for the variable "type of domestic customer", where a significant difference appears between those firms that are only serving regional markets (where demand for low-tech products exists) and those firms that are serving large domestic firms or subsidiaries of multinational-national firms, where demand for technically advanced products exists.

Using the variable "competition based on quality and performance" to claim that demand-pull influences are at work is more problematic because this variable can also be interpreted as a proxy for specific management goals or strategic objectives, not necessarily dictated by external market forces. It is reasonable to admit that competitive pressures would underlie a defensive-type strategic commitment, but one can also admit that this commitment came before any competitive factor had forced it into being. There is the possibility that a conscious and intrinsic consideration of the issue was, at some time, introduced into the firm's routine approach to product conception. If it was the case, then the variable would be better placed in the "management" category. To take account of the ambiguity the variable should be perceived as lying in a limbo between the two categories. The causal direction of this factor is open to doubts. It can either be considered as a consequence of market pressures or as a managerial cause of innovative behaviour.

10.4 Education and management style

Another similarity between the results of this study and other studies lies in the variable related to educational level. The results show significant differences between the two groups of firms concerning this variable. The existence of graduate personnel is apparently related to the degree of innovativeness of a firm. The difference is also strong when we consider the variable "graduate intensity" (the ratio of graduate personnel to total employment).

Table 50. Descriptive statistics of the variable “graduate intensity”.

	N	Minimum	Maximum	Mean	Std. Deviation
Average group	9	0	0.26	0.042	0.0848
Innovative group	10	0	0.31	0.092	0.0901

Table 50 shows the statistics related to this variable. The mean intensity amongst the “average” group is less than twice the mean intensity amongst the “innovative” group. The minimum value for both groups is zero but there is only one such case in the “innovative” group while there are four such cases in the “average” group. It relates to the importance of having management of high quality and ability, pointed out by other studies, but it also reflects the importance of having personnel with high technical competence.

The importance of management style (openness, horizontal and organic features) is also pointed out in those studies but we found no significant differences between the two groups of firms concerning that. There are two possible reasons. First, the firms in the sample are all relatively small-sized, with one exception, so that the horizontal and organic nature of the relationships arise naturally. Indeed we found that communications between owners, managers, mid-managers, technicians and workers were, in general, very fluid and easy to establish, not constrained by bureaucratic barriers and facilitated by the often small premises on which the firms operated. Very often the interviewees stressed the team spirit of the firm and even the presence of quasi-familiar modes of group interaction, and the two-way spirit of loyalty that existed between employers and employees. Simões (1995) also refers to “pre-Taylorist” modes of organisation in Portuguese firms and says they are not uncommon. Second, the considerable handicraft nature of the work involved and the type of skilled work force employed implied that the contributions emanating from the bottom were not taken light-heartedly, and that the contribution of the work force in certain aspects of the creation of the product was accorded significant importance. The style of management was, both in the "average" and in the "innovative" group, essentially organic, or, as it was described by one of the interviewees, "rigidly flexible". This homogeneity derives, to a great extent, from the fact that we are dealing with only one sector, possessing specific idiosyncratic features of operational behaviour. Had we considered more sectors, this homogeneity may not have emerged. However, it suggests that the type of management is not, at least, a sufficient condition for innovative success.

If we take a closer look at the response distribution of the "existence of graduate personnel" variable in Annex B, the same conclusion applies regarding the educational level, since there is a considerable proportion of "non-innovative" firms that do possess graduate level personnel. On the other hand, the variable "graduate intensity" (cf. Table 50) suggests that the level of investment in the educational level does seem to play an important role in the determination of the innovative performance of the firm.

10.5 Planning activities and management techniques

Another point of confluence between this study and other studies is the importance of careful and precise planning activities and the use of management techniques. The variable "type of strategy" is a proxy of the factor. The majority of the firms in the innovative group had some kind of formal planning procedure in place. Half of them planned their activities at the medium-term and long-term level, which involved, one the one hand a detailed one-year or two-year plan (some firms even had a three-year plan) with quantitative objectives regarding costs, investments and sales, and on the other hand a long-term (usually five-year) plan that detailed the overall objectives and strategic orientation of the firm. The other half was split between those who had a medium-term formal quantitative plan and those that did not have a formal plan but did nevertheless have a strong strategic perception of what the firm should do, how to do it, and when do to it. We have labelled this mode the "visionary" type of strategy whose characteristics could not be mingled with the other type of approach to strategy making, common in many of the "average" group firms. This other approach is rather a non-approach, in the sense that there was no clear visible strategic perspective, and the firms were essentially engaged in the mere day-to-day running of the business apparently not worried about the possible threats that future changes could bring to them. More than that, they didn't seem to be engaged in any kind of prospective exercise to evaluate possible future trends. This type of strategy was labelled "short-term". The results suggest a strong association between the different types of strategy-making and the innovative performance of the firm.

10.6 Propensity to risk

The two variables named "main source of funds for investment" and "receiver of subsidies" are associated with risk-taking behaviour. Although the relationship with innovative performance is not strong, particularly in the first variable, it suggests that firms willing to take a real risk by resorting to outside sources of finance, e.g., by borrowing from the banks, are more likely to succeed. As it regards the second variable it should be noted that the subsidies under consideration are not entirely risk free. First, they required previous investment from the firm and did not cover the total investment. Second, due to bureaucratic delays in the payment of subsidies to the firms, these had to borrow more money than intentionally envisioned, so that, in the end, it turned out that the subsidies, in many cases, paid only the interest on the loan. It should also be noted that, in Portugal, borrowing from banks could be a really risky move because the interest rates were very high. In the early 1980s the yearly interest rate could be as high as 30% . Nowadays it has levelled down to a more manageable figure.

10.7 Technological determinants

The results of the variable "separate R&D department" show that the commitment of the firm to invest in this kind of resource is significantly linked to innovative performance. This link was also evident in other studies. As we understand it, it is a definite option taken by the firm to act in a certain way and it expresses the importance it attributes to technological development, as opposed to those who regard product development as a low-priority task and choose to base their chances on other options or do not perceive any advantages in doing so.

If this variable is considered as a proxy for technology-push determinants in innovative performance (in the sense that an R&D department embodies the capability to organise resources related to scientific and technological knowledge with a view to achieving advances that can be translated into the development or improvement of products) and that without such an arrangement innovative performance is less likely to be successful, then its significance suggests that technological factors seem to be as important as the factors related to demand indicated by other variables.

This dependence of innovative performance on technological factors should be analysed in conjunction with the significant relationship shown by the variable "graduate intensity" mentioned earlier, if we assume that the increase in graduate intensity is proportional to technical personnel involved in development activities. The argument is also strengthened by the strong association suggested by other variables. The superior level of production equipment exhibited by the "innovative" group, the importance attached to equipment upgrading, the consideration given to quality issues revealed by the existence of separate quality control laboratories, and the considerable use of CAD and (less often) CAM, all point in the direction that the capability to take advantage of scientific and technological advances in the firm’s own field and the capacity to exploit technological opportunities opened up by generic technologies are indeed crucial determinants in innovative performance.

10.8 Approach to product conception

The variable "approach to product conception" is a reflection of a particular kind of difference that showed up in the interviews and it is related to the way firms face their task of producing machines. The variable differentiated between two approaches. One the one hand, we have firms claiming that they do not sell machines but rather an operation. In their view there are several ways of performing a given operation and their task is to provide the best possible way of performing that task. In this sense, they see themselves more as service providers than as producers of machines. As a consequence, they spend a considerable time evaluating the environment in which the machine (operation/service) will be integrated and in considering the limitations, possibilities and technical synergy available and the interfaces required. In contrast, we have the firms that see themselves as producers of a specific type of machine in which they are skilled. The machine performs a single type of function and it is up to the customer to integrate it in the overall production process. The general attitude is: "this is what we do; we may make some modifications here and there to accommodate your requirement, but basically that is what the machine does and it can go no further than that". The former kind of attitude seems to be conducive to a much more creative state of mind, and the potential to search for new ways of doing things and to open up new perspectives when dealing with technological bottlenecks is much greater. Not many firms, even in the innovative group, showed this approach and the distribution of responses between the two groups is not particularly sharp. But it is an additional argument and explanation of the importance of the technological determinants of innovative performance.

10.9 External sources of knowledge

Some interesting relationships showed up concerning differences between the impact of external sources of knowledge on innovation activities. One interesting difference is that the impact of universities on scanning activities was greater for the "average" group than for the "innovative" group. In principle, one would expect that innovative firms would be closer to universities than the less innovative groups, and that the innovative firms would take more interest in new knowledge and its potential for new applications than the other firms. This apparent incongruity can be explained with the notions of appropriability. First, the technological knowledge used by the sector is relatively mature, whether it is mechanics, electronics or even optics, and it is not strongly science-based, and consequently much of it is in the public domain. Second, the innovative group have largely embodied that knowledge within their own structure, encapsulated by the graduates and the highly skilled technical personnel they employ. What they search for is not knowledge with a high public content but rather knowledge with a high tacit content, one with the higher potential to improve their competitiveness. That is not to say that they do not have relationships and co-operation activities with universities, which most have. However, they seem to happen at a rather informal level. Contacts between ex-university colleagues or teachers are common. Co-operation is sought at very specific levels and in very concrete subjects. Very often it is related to solving a particular bottleneck in production processes, when the internal capabilities of the firm fail. Another common area of co-operation is at the level of technical calculus that requires either a deep understanding of a mathematical sub-area or the need to take advantage of specific equipment with powerful computation facilities, e.g., to perform simulations, the kind of equipment that the firm does not have. The average group of firms, on the other hand, because of their often considerable limitations in educational levels, or graduate intensity, and consequently in their knowledge base, often find the contribution of the university very valuable, even if the level of knowledge provided by the university is modest. What is public knowledge for the innovative firms has not, in many cases, been appropriated by the less innovative firms. The knowledge transfer may be in the form of a specific technique to handle a certain type of material, a change in designs of parts to achieve certain movements, or even a simple mathematical calculation of power requirements, all of which can be considered to be in the public domain but which are not mastered by the non-innovative firms due to their low absorptive capacity.

The notion of absorptive capacity and the degree of "public" knowledge appropriated by the firms also explains the interesting relationship between suppliers and scanning activities of the firms. For many of the "average" group firms, an important source of knowledge comes from the suppliers. The suppliers act as intermediaries between their knowledge base and the forefront of technology, bringing to them information on advances in many areas of interest to the firm such as new materials, new tools, new production machinery and even new techniques. Again, much of the information provided by the suppliers was already appropriated by the innovative firms (the supplier works often for these firms) and in many cases it can be considered to be in the public domain.

The mechanism by which knowledge is appropriated by the two groups of firms can be partly explained by the informational networks which they are part of. We noticed in the interviews that the managers of the firms in the innovative group were apparently moving in the same social circles. They knew each other and were very aware of the activities each one was pursuing. They seemed quite intimate with the strategic perspectives and the managerial approach of their peers, and even their historical background and experience. The same happened with the "average" group, but to a lesser extent. Apparently there was a social divide cutting across the two groups of firms, with the consequence that the information flowing to each of them was quite different, thus explaining the degree of public (or tacit) knowledge appropriated by each group. Von Hippel (1988) has described how these kinds of informational network build up and how knowledge is transferred between firms within the networks. The relationship between fairs and innovation seem to indicate that the two groups of firms make part of different social groups. The greater importance attached by the “average” firms to the knowledge obtained in trade fairs is probably an indicator of the lack of alternative ways of obtaining knowledge. The differences related to the variable “receiver of subsidies” may also be an indication of the social divide separating the two groups. The technical capacity to apply for subsidies and the social contacts and tacit and informal information required for a successful application are ultimately behind the observed variation. Together with the fact that the firms possess different knowledge bases at the start due to different educational levels, such a kind of dynamic would explain the disparities showed by the two groups of firms.

10.10 Conclusion

Analysis of the case studies resulted in the identification of a set of variables whose patterns of distribution between the “average” group and the “innovative” group of firms showed significant and important differences. The variables were grouped into five categories. The “tangibles” category includes variables related to the characteristics of the production equipment of the firm, the “intangibles” category includes factors related to educational and technical skills of the firm, the “management” category includes variables related to management skills and philosophy, the “external stimuli” category includes variables related to the impact of external demand factors on the firm and the category “external sources of knowledge” includes factors related to the way information and knowledge is appropriated by the firm.

The results show that either factors related to demand conditions (heralded by the demand-pull theorists as the main determinants of technological change) or factors related to supply conditions (heralded by the technology-push theorists as the main determinants of technological change) are significantly related to differences in innovative behaviour. This conclusion is in line with earlier studies concerned with success and failure in innovation. However it also seems that none of the factors, per se, is a sufficient condition for innovative performance. For instance, the mere existence of graduate personnel in the firm, or the management style, are not unequivocally related to innovative performance, nor the fact that a firm employs advanced production equipment implies necessarily that the firm is more innovative relative to a comparable one (see the distribution of variables in Annex C). Nonetheless, and in general terms, the identified variables reveal substantial differences between the two groups of firms and several explanations for those differences are suggested. A subsequent and logical goal now is to understand how the variables interact with each other and how the influence of each factor, per se, or in interaction with other variables, can be explained. The next chapters will address those issues.

CHAPTER 11. FIRMS' HISTORIES, DIVERGENCE PROCESSES AND SELECTION CRITERIA

11.1 Introduction

If the set of characteristics that distinguishes one group of firms from another is not coincidental or circumstantial, then one of the main issues to be addressed is how to explain the simultaneity of the identified constituents and how are they related to one another and to the innovative performance of the firm. The considerations exposed in the previous section about the differential pattern of each group gives only a snapshot of the present situation and does not give an entire explanation of why firms got where they are. What are the mechanisms underlying these trajectories and what caused firms to diverge in their path? These are the questions the answers to which I will now try to contribute. To that purpose maybe it will be useful to look at the history of the firms that were studied.

When working within an evolutionary framework of analysis it is fundamental to consider the mechanisms and criteria of selection. Above we said that we simplified the matter by assuming that innovative performance was the measure of fitness and that the selection criteria were based on that. In reality, the matter is not so simple. Firms with varying degrees of achievement coexist, which calls for the identification of other selection mechanisms. On the other hand, firms with similar levels of innovative performance are selected according to other criteria.

We recall that the methodology used in this study to address the preceding considerations consisted of matching together pairs of firms, one of which is labelled the “innovative” firm and the other one is labelled the “average” firm (cf. Chapter 2), thus forming two groups of firms, respectively the “innovative” and the “average” group. Table 51 lists the case studies to follow (cf. also Annex A).

Table 51. Pairs of firms.

Pair	"Average" group			"Innovative" group		
	Name	**Present products**	**Size**	**Name**	**Present products**	**Size**
1	Arvorense	Lorry bodies, agricultural machinery	30	Herculano	Agricultural machinery	200
2	Vima	Conveyors, dumpers	60	Mano	Conveyors	110
3	Avense	Components for textile machinery, textile machinery, other machinery	23	Industrial	Components for textile machinery, textile machinery	40
4	Frama	Wood-working machine-tools	82	Pinheiro	Wood-working machine-tools	290
5	Mecano-Textil	Textile machinery	140	ACL	Hydraulic components, lifting gear, presses, textile machinery	70
6	Maquisis	Metal working tailor-made machine-tools	19	Seri	Metal working tailor-made machine-tools	16
7	Sersan	Machine-tools for the cork industry	25	Prensarte	Machine-tools for the cork industry	19
8	Diarroca	Components, presses	25	Adira	Press brakes, guillotine shears, presses	250
9	Mecver	Components, presses	49	Guifil	Press brakes and guillotine shears	103
10				Efacec	Electric power stations, electric and electronic machinery, software	2500

Note: Size is measured by the total employees of the firms.

Selection based on innovative performance seems to be the case in the example provided by pair 1 (although other factors were also important) where the firms were operating in the same environment (see below). In other cases, the environment itself is not homogeneous, but multifaceted, and the selection criteria are also multifaceted. In our study of the capital-goods sector we found that firms face an environment that is composed of firms with varying degrees of innovative performance or behaviour, thus characterised by the existence of several demand curves. The multidimensional nature of the environment implies that the criteria of selection and the variables on which the firms ultimately will be selected are also multidimensional. That fact partly explains the variability of performance and behaviour in the population of firms. To survive, a firm does not have necessarily to adopt all factors favourable to innovative performance. It will selectively adopt those that will make it better suited to the particular sub-environment on which it lives.

In the following lines we will advance explanations of firms' variational behaviour and performance based on the comparative analysis of the pairs of firms introduced above and resorting to evolutionary theory and concepts. First we will describe and suggest explanations for the evolution of each firm, taken individually but always in the context of its pair. During that analysis the fundamental lines of reasoning and the core approach to the subject will emerge as it will be repeatedly applied to each case/pair. The systematisation of such an approach and such a line of reasoning will be made after the thorough exploration and analysis of each case study and it will result in the suggestion of generalisations and of a formal model and theoretical approach which will introduce a degree of analytical order into the various events described and previously analysed. Thus, this chapter is not only descriptive. As was said above, it aims also to prepare the ground, in a thorough manner, for the next one, which will generalise the individual analysis. Histories are written as off 1996.

11.2 ARVORENSE and HERCULANO (Pair 1) – to be more equal than others

Two firms that are both producers of agricultural machinery constitute pair 1. The pair is quite useful for our purposes because their product lines are very similar and their fates seem to be inextricably linked. It is the most comparable of all the pairs in the sample, not only because of the similarity of its product lines but also because of juxtaposition of its potential market. In this example the firms evolve in almost opposite directions after an initial balanced period. Both firms started from humble beginnings in the first half of the century, as one-man firms. The founders were blacksmiths forging basic manual agricultural tools such as shovels, axes, spades, rakes, etc. Both developed into family-owned firms by the 1930s. They started manufacturing somewhat more complicated products such as ploughs and trailers adopting other techniques, e.g., foundries, casting and soldering, and subsequent introduction of machine-tools took place. By the 1950s the "innovative" firm reached an industrial stage, with production being fairly based on machines and greater division of labour, and not so much on handicraft methods. This stage was reached in 1960 by the "average" firm. By this time the main products were simple and special purpose trailers, ploughs and a closely connected family of products, such as cultivators, drills and disk-harrows, all designed to be coupled to tractors (which were diffusing at a higher rate than before).

During that time, the sons of the founders had achieved different educational levels. Those from the innovative firm were educated at professional technical schools, while those of the average firm only went through basic school and learned their professional skills on the job. It is interesting to conjecture why it happened like this. Both families had similar backgrounds and enjoyed considerable success in their activities. Both were located relatively near to large cities and educational facilities. If sociological or geographical considerations are not enough, then the explanation for it can only be found at the psychological level. In this context of explaining innovation differentials, the event can only be considered as a random outcome of a complex and inscrutable process of the mind. It will have considerable consequences on the trajectories of each firm due to its "expanding" or cumulative features. This event can be considered as a point of divergence that will drive the two firms in different directions, as the impact of the occurrence will have an effect on the future of the firms. This event will have considerable impacts on the trajectories of each firms.

The implications of such social-technical decisions on innovative performance begin to show up in differences in the characteristics of the products, the complexity of the products within reach of each firm, the modes of organisation, techniques of management and cost reduction strategies. The situation worsens as the educational lag deepens even further. The owners of the innovative firm attains university level while those of the average one attain only secondary vocational technical level. The implications for cumulative learning and the expansion of the knowledge base are increasingly important, affecting all aspects of the firms, in a positive way for the innovative firm and in negative way for the average firm. The situation is worsened by the fact that the firms are direct competitors. Eventually the average firm is unable to cope with competitive pressures and in order to survive it has to resort to another market, meaning a simpler product and actually moving backwards, because it ceased to exercise all its skills.

But these repercussions will not be felt immediately. Let us see now how they occurred. In the early 1970s both firms engaged in ambitious expansion projects and they both diversified into new product lines. However, considerable differences began to show up in the characteristics of the products. The new mechanical techniques learned in the technical schools, the theoretical context in which they were taught, as well as the ancillary disciplines related to production management and accounting practices started to express themselves in the form of more reliable products, better applications of pneumatic devices, and more cost reduction savings later invested. Later, the educational lag deepened even further. The third generation of the innovative firm was educated at university level, while the third generation of the average firm was educated at vocational technical level, the level at which the previous generation of the innovative firm was educated. The social networks in which the firms are now immersed are very separate. The implications for cumulative learning and the expansion of the knowledge base are crucial.

Those implications become visibly clear when the innovative firm started to hire engineers, in the early 1980s, and re-structured its organisation to include a department concerned only with design and development. Its products were subject to increasing refinements, namely at the level of new materials, improved finishing, broader applications and sophistication of hydraulic components and controls, and new designs in mechanical parts to improve coupling with the power source, and the ease and reliability of operation. Planning procedures multiplied, reaching every type of activity of the firm, from the operations level to the investment level. Continuous training became a routine activity and was applied at every level.

By the early-mid 1980s the products were widely superior to those manufactured by the other firm and the range of products was broader. Sales grew and were now affecting directly the sales of the other firm, which were sinking for some time.

Other important events also took place. The innovative firm adopted an aggressive marketing policy, definitely abandoning its regional tradition towards a national dimension. It built an ever-growing network of representative agents, which not only sold their products but also provided technical assistance, with personnel trained by the firm. It started to export in the mid 1980s, first to Africa then, very soon, to France, a market that proved to be more regular and consistent than Africa. They now export around 30% of their production of which 80% is destined for France, Spain and Germany. They also have engaged themselves in sub-contracting activities with French and German firms. They have agents in all those countries. Recently they built two factories in African countries and are now trying to build one in France. They have also been involved in several co-operation agreements with universities, both at the training level, and at the development level (in an application of optic devices to planners). In the early 1990s the firm embarked on a huge investment that covered building of new plants, acquisition of new automated production machinery including a robot, automation at the level of administration, accounting, production costs control, stock management and CAD.

In the meantime the other firm acted quite differently. During the 1970s the firm also expanded and diversified into somewhat more sophisticated products, such as frontal loading cranes to adapt to tractors and other functionally differentiated machinery to be coupled to tractors (the other firm was also active in most of these product lines). However, these products demanded a design expertise that was gradually surpassing the skills embodied in the personnel of the firm. Knowledge of mathematical and geometrical principles, and techniques necessary to design articulated components and parts, were either out of reach of the present knowledge base of the firm or were becoming more and more costly to learn (generally involving numerous trial and error experiments not guided by a solid theoretical background). However, the firm did not manage to circumvent that obstacle by hiring skilled engineers, for instance, or by resorting to external technical advisors, even though they were aware of the developments going on in the innovative firm. The lack of action may have been caused by lack of funds, or inability to see beyond their present circumstances, relying excessively on their own capacities, or insufficient risk taking attitudes. Whatever the case, the firm went on a downward spiralling course. No new acquisitions of machinery or improvements on the existing stock were made. The machinery they now possess is twenty-five years old and virtually unchanged. No attempts were made to expand beyond their regional level of activity. Sales relied on market arrangements with sales outlets that were increasingly reluctant to buy their products. Many were now agents for the other firm. Sales sunk by the mid-1980s, at which time the firm decided to concentrate on manufacturing and repairing lorry bodies, relying on the knowledge and the machinery they acquired when manufacturing agricultural trailers. Note that the capacity required to build lorry bodies is lower than that required building trailers, since the later often incorporated additional devices and machinery to serve explicit functions (pumps, motors, pressure gauges, etc.). In this sense, the firm followed an unlearning path because it ceased to apply on a repetitive basis the skills and knowledge it once applied.

The above comparison is an extreme one, where on the one hand we have one firm steadily building in a cumulative way its capacities and achieving considerable success, and on the other hand we have a firm that is strikingly characterised by the incapacity to move ahead from where it stands, and actually moving backwards, because it ceased to exercise all its skills.

But the story could have turned in another way, had the average firm chosen at least to act in specific areas that could mitigate the limitations of their knowledge base. It could, for instance, have improved its capital stock, enabling the production of better quality products, even if that implied divesting some of their range of products. The same applies for training activities. It seems, however, that their main problem was at the level of construing a coherent course of action and their incapacity to react to changing circumstances.

11.3 VIMA and MANO (Pair 2) – when innovative capacity is not enough

The example provided by pair 2 depicts a situation where several factors are already in place, specifically high educational levels, upgraded production machinery and a rather well defined strategy, but where divergence between the two firms occurs at the level of

R&D and risk attitudes. Both firms produce conveyors or conveyor systems for handling intermediate stages of the production process.

The average firm relies on the technological knowledge of the owner/managers, who have been together since the inception of the firm, thirty years ago, and who are in charge of every aspect of the product cycle, from conception and design to production. There are no clear boundaries between departments, and none of them is exclusively concerned with development. They produce good but relatively non-demanding products. They only build conveyor systems to transport unitary solid components. The integration between mechanics, electronics and software is reached at a relatively simple level, were the path is essentially linear and the bifurcation decisions involve simple algorithms. On the other hand, the innovative firm has an R&D department and it pours many resources into development work and hiring new engineers for R&D activities. The products are of better quality and reliability, and they build systems that are not only able to deal with unitary solid components but also with continuous non-solid components. It produces also complex, integrated large systems that the other firm is unable to do, due to lack of personnel and its lower capacity to integrate complementary technologies such as software and electronics. The innovative firm exports 40% of its production to France and England while the other firm serves the domestic market. It seems apparent that the firms diverged due to the way they took advantage of their knowledge base and how cumulative effects building on their technical know-how enhanced the performance of one firm against the other. In this case, the relevant factors are related to risk attitude and the greater strategic importance attributed to R&D activities.

The father of the present Director/Owner and another partner established the innovative firm in 1961. Initially it was dedicated only to the commercialisation and servicing of agriculture equipment imported from Germany, but very soon it initiated its own production. It specialised since its beginnings in the production of conveyors and transportation systems. Initially the production was geared towards the agricultural sector and the machines were quite small and simple. Basically they were made of a metallic structure usually 3 metres long with small wheels, and a motor linked to a transmission system based on chains that moved a belt. Its purpose was to load cargo into vehicles. The educational level of both partners did not exceed the 5th year of schooling. The know-how was based on previous experience, observation of similar products and mechanical tinkering by the partners.

Although the products were quite simple, by the end of the 1960s there was already visible a considerable product diversification. Based on the same basic pattern and structure they produced a diversity of conveyors adapted and modified to serve different purposes, i.e., adapted to transport different types of agricultural products. Since the beginning, production was based in a rather narrow product definition but with a rather broad approach within that narrow definition. Its marketing approach was precisely based on tailor-made production, adapted to different products.

The sectoral narrowness of its client base, initially restricted to the agricultural sector, was soon enlarged to comprise other sectors of activity. The technical evolution of the firm was apparently regular although there were some difficulties along the way. It certainly benefited from the expansionist economic period of the 1960’s and early 1970’s and it probably suffered with the recessions of the mid 1970s and early 1980s but the firm enjoyed steady success and it enjoyed also regular growth. It started to export to the then Portuguese African colonies. It hired technically trained personnel and the son of one of the founders (and the successor of his father) went through higher education and assumed the control of the firm in the early 1980s.

This man is optimistic relative to the future prospects of the firm. His optimism relies on the positive evaluation that he makes of the soon to came accession of Portugal to the EEC. This event represents to him the possibility to access the large European market. To prepare the firm for that event there was a large investment in buildings and machinery in the early 1980s (1982-1983) which represented a turning point to the firm and a considerable upgrade in technical and production terms. The cost of capital was extremely high (an interest rate of 30% per year) and to optimise that investment the firm also bet heavily on product development and started to seek actively for large customers.

It set up a department solely concerned with product development with a total personnel of fifteen people, of which 3 were mechanical engineers. There were also engineers in charge of production and in the marketing department. Following its initial intentions the firm started to export to the European market but it faced more difficulties than expected and the initial optimistic expectations were never quite fulfilled. The maximum share of total sales they were able to export reached only 40%, which although quite a considerable figure seemed not enough to sustain the debt acquired with the investment.

The main foreign clients were in France and in England. The firm acted essentially as a sub-contractor and it manufactured in large series for foreign clients. Technical relationships between them and contractors were intense. Usually the clients requested a solution to a problem formulated in generic terms. The problem was generally one of automation of warehouses or production lines. The firm is now quite distant from the production of single small units for the agriculture sector. Now its main products are complex and large integrated systems for large clients, be they national (such as systems for large national manufacturers of consumer products, systems for handling mail at the post office, systems for handling luggage at the airport, etc.) or international (usually involving much larger quantities and serial production). The solution proposed by the firm to the situation and specifications described by the contractor is very detailed, involving project conception, engineering, the precise definition of the machines and its principles and modes of operation, the specification of the transport lines, etc. Afterwards there are many meetings and contacts with the contractors to define and make precise every technical detail. Prototypes are often manufactured and sent to the contractors for testing and eventual redesign before any production starts. Asides from its own technical and scientific capacity and the knowledge shared with the contractors the firm also has regular collaboration with consultants from other firms in the sector.

The main competence of the firm is in the mechanical area. Almost everything related to electric and electronic components is contracted out. The firm maintains only a small competence in terms of electric components. Personnel are submitted to regular training in the national specialised centres linked to the professional association.

Occasionally other firms provided training. On the whole there is a preoccupation to keep the skills of the production personnel updated, asides from or in line with its concern with the need to keep highly qualified engineers on product development. Thus the firm contains all the ingredients, at least at a reasonable level, necessary to be quite successful in terms of innovative performance and capability, which it is.

But there are other factors in this case that will complicate the equation, namely those linked to strategy, planning and marketing. The weak points of the firm are to be found there. But before referring to them lets us take a look at the average firm.

The average firm was founded at around the same time as the innovative firm, only one year later in 1962. Contrary to its innovative counterpart it was founded by highly trained people, namely three engineers (one mechanical engineer and one electric engineer devoted to product development and production, and one electric engineer with administrative functions). Before setting up the firm these three individuals worked on a large firm that imported motors and provided technical assistance to their owners. The engineers were linked to the technical services provided by that firm. Later this firm started the production of components. It is then that the three engineers, profiting from the know-how acquired on such activities and from the strategic decision of the firm do divest certain lines, decide to start their own firm acquiring the buildings and the equipment allocated to production and technical maintenance of the motors from the large firm. The firm started with the production of dumpers and conveyors.

Similarly to the innovative firm, the firm will profit from a particularly good economic environment in the 1960s and early 1970s. Until the mid 1970s all goes well for the firm. In the mid 1970s the recession imposed hardship on the firm. One of the initial partners decided to quit and a new partner/engineer took his place together with some employees that acquire a minority share. By the late 1970s the firm seems to take its feet and decides to start a new product line, namely the manufacture of forklift trucks, a product that combines the two other product lines (dumpers and conveyors) in one. The technology employed by the firm also enjoyed an upgrade. Hydraulic principles replaced mechanical principles which resulted in the introduction of hydrostatic transmission and brakes in the forklift trucks, and the introduction of hydraulic movement of the container of the dumpers. The main change in the conveyors was the diversity of design they were enjoying. Production was also subject to re-organisation. In 1986 it was again subject to expansion investment and it benefited from the expansion of the economy. Unlike the innovative firm, investment seldom was made by resorting to the bank. In most cases the firm used its own funds and it only resorted to the bank for short-term (1 year) loans. One of the partners also left the firm. Equity was now evenly distributed between 4 partners (which included the minority ex-employees). Conveyors were now the main products representing 70% of total sales. The product was subject to a substantial technological upgrade specifically with the introduction of electronics and computer control. Above all, the product was now designed as a system and not as a single product. Involvement of the client became more important and decisive to the success of the product.

Unlike the innovative firm the average firm relies on the technological knowledge of the owner/managers, who have been together since the inception of the firm more than thirty years ago and who are in charge of every aspect of the product cycle, from conception and design to production. There are no clear boundaries between departments, and none of them is exclusively concerned with development. They produce good but relatively non-demanding products. They only build conveyor systems to transport unitary solid components. The integration between mechanics, electronics and software is reached at a relatively simple level, were the path is essentially linear and the bifurcation decisions involve simple algorithms. On the other hand, the innovative firm has an R&D department and it pours many resources into development work, and hiring new engineers for R&D activities. The products are of better quality and reliability, and they build systems that are not only able to deal with unitary solid components but also with continuous non-solid components. It produces also complex, integrated large systems that the other firm is unable or unwilling to do, due to lack of personnel and its lower capacity to integrate complementary technologies such as software and electronics. The innovative firm exports 40% of its production to France and England while the other firm serves the domestic market and exports a small share of its production (5% of total sales) to not very demanding clients in African countries.

It seems apparent that the firms diverged due to the way they took advantage of their knowledge base and how cumulative effects building on their technical know-how enhanced the performance of one firm against the other. In this case, the relevant factors are related to risk attitude and the greater strategic importance attributed to R&D activities. However there are some caveats in the behaviour of the innovative firm. The risky and large investment that the firm made in 1982-1983 was apparently not based on thorough market research and a well conceived and structured plan. It apparently relied to a great extent on non-substantiated subjective perceptions of the owner. The size of the investment would also require the firm to maintain a minimum regular production scale (i.e., mass production). The machines acquired by the firm were not prepared for batch production nor did the firm have such a perspective in mind. In fact they wanted to get away from that mode of production which had characterised its modum operandi since its early days, as described. There was apparently also a certain disregard for market activities. For instance the firm did not have a permanent physical structure or representative in the UK, which was the country where one of its main contractors was based. It also did not diversify enough its client base and its export markets, making it dependent on a few contractors based on only two countries. When France and the UK entered a period of recession in the early 1990s the firm was not prepared with alternatives to face the shrinking demand from the firms in those countries which constituted, by virtue of the large nature of their orders, the main clients supporting the scale production strategy of the firm. When the agreements with those firms broke down the remaining clients were essentially the national clients and these ones were not large enough to support the mass production strategy of the firm. Against its will the firm had to resort again to tailor-made production but the existing physical and cost structure was not aimed at such an activity. The strategic approach to mass production instead of batch production seems to be the main problem behind the situation of the firm. Its choice was too bold and risky and it run against the trends of the time. The average firm, on the other hand, relied more and more on batch production and less and less on the products more conducive to mass production (dumpers and forklift trucks). It maintained always a light structure and expansion was made with caution and by the cheapest possible way (i.e., avoiding large loans).

In 1992 the situation was becoming untenable for the innovative firm due to debt escalation. It was then confronted with two alternatives. Either merge the firm with a foreign multinational or sell 50% of its equity to a venture capital organisation. It chose the last one trying to maintain power over the firm. But the situation did not improve. Recession was slow to reverse trends or its effects on the firm, in part because of the nature of the equipment goods sector, which is the first to feel the effects of the recession and the last to feel the economic recovery, and the financial situation worsened. The firm is now close to ceasing its activities. This example is curious, in terms of selection criteria, in the sense that the more innovative and dynamic firm is the one for which survival prospects are more reduced. The cause is not linked to lack of product development or to the quality of the products but rather to a deficient global strategy or to a deficient implementation of that strategy. The situation can be explained by the fact that the risk attitude was not accompanied by adequate management support, namely lack of rational prospective market research and insufficient marketing.

11.4 AVENSE and INDUSTRIAL (Pair 3) – surviving with a limited knowledge base

The histories of the firms in pair 3 illustrates how firms face several alternatives to improve their chances of success, even if there are intrinsic limitations in the knowledge base. Both firms manufactured mechanical looms, but competition from abroad seriously challenged their chances of survival. The educational level in both firms was at the secondary technical level.

The innovative firm decided to abandon the production of looms because, after several attempts to upgrade its product, it concluded that it was not in a position or willing to take further risky investments in development activities. After a long search for alternatives it identified a family of products for which it perceived enough demand opportunities that, coupled with the firm's specific knowledge and cost advantages, would render its production feasible and lucrative. The product niche on which it grounded itself was in complementary machinery for the textile industry (lifting and transport gear). It also continued to manufacture components for looms. At first, the same mechanical skills used in the construction of looms were applied to the new product lines, then it gradually added hydraulic and other electric means of control. Over the years there was a persistent concern with the upgrading of the product and with the production machinery to fulfil quality requirements and cost constraints. It has also maintained uninterrupted efforts to keep abreast of new developments in the sector, by participating in international fairs, other important events, and in maintaining contacts with production engineers in customer firms. Most of its clients are large textile firms and it exports components to Swiss textile firms.

The firm in the average group persisted in the manufacturing of mechanical looms, although demand was shrinking daily. It did not attempt to improve its educational level and knowledge base, nor did its attempts to improve its products, based always on a mechanical paradigm, bear any results. Search activities were scarce and the firm did not find a viable alternative. It began to rely more and more on component production and repair of old machines still in operation in local textile firms. Eventually it began to accept and look for any opportunity to manufacture components, even if not directly related to the textile sector. Occasionally it finds a local customer that still wants a machine (not looms) based on mechanical operation, well within its technical capabilities and knowledge base that has remained virtually unchanged. No resources were spent in training the workforce and no investments in new machinery or improvements in existing machinery were made. It now seeks desperately a market niche on which to survive but its efforts in scanning and search activities are weak and restricted.

The innovative firm was established in 1942 in the place where it is today. It started with the production of looms and other machines for the textile sector. The father of the present owner/manager founded it. The family had a tradition of working in the metallurgic sector. The father of the founder was involved in the maintenance of machines for the textile sector and the grandfather of the owner was himself skilled in the trade (apparently he adapted old guns).

The products were based on mechanical principles. All looms were mechanical with no automatic devices whatsoever. The mechanical tinkering of the founder was the fundamental technical and knowledge asset of the firm but it was also its greatest liability in terms of management. By 1958 the firm was technically bankrupt and the cause had more to do with deficient management in terms of cost control than with the inability to sell the product. The son of the founder took over the management of the firm and the founder was committed only to the technical function. The firm initiated a difficult period of financial recovery that lasted some years. The persistence of the present manager and his acute cost-consciousness avoided the collapse of the firm. The production lines remained the same, namely looms, adaptation and upgrading of old looms and other machines for the textile industry, but sales were decreasing due to the increasing technical obsolescence of the products, particularly the looms which remained essentially the same. The technological improvements in the looms were basically based on change of design to accommodate and adapt the machinery to the manufacture of different pieces of cloth or to work with different types of tissue. They also adapted some devices that rendered the looms semi-automated. However, competition from large European manufacturers with technologically advanced machines and the ever-shrinking base of national clients compounded the difficulties of the firm.

After several attempts to upgrade its product, the firm decided to abandon the production of looms because it concluded that it was not in a position nor was it willing to undertake further risky investments in development activities. Probably this decision involved a conflict between the technical interests and tinkering of the father and the pragmatism and cost-consciousness of the son. After a long search for alternatives the firm (through its manager who was now in full control and the main autocratic driving force of the firm) identified in 1968 a family of products in which it perceived enough demand opportunities that, coupled with the firm's specific knowledge and cost advantages, would render its production feasible and lucrative. The new product family was not manufactured by any other firm domestically (everything until now was imported) a factor that weighed heavily in the choice of the product (the firm could manufacture the product with a price advantage relative to foreign competitors, aside from the fact that it could provide more timely product assistance). The necessary know-how to manufacture the product was well in reach of the firm. As in other examples mentioned in this study, there is here a unlearning movement by the firm when it switches to another simpler product line, but in this case it is followed by a learning movement concerned with the constant improvement of the simpler product. The product niche in which it grounded herself was in complementary machinery for the textile industry (lifting and transport gear). It also continued to manufacture components for looms. At first, the same mechanical skills used in the construction of looms were applied to the new product lines, and then it gradually added hydraulic and other electric means of control. Over the years there was a persistent concern with the upgrading of the product and with the production machinery to fulfil quality requirements (quality control is a current practice and it is contracted out) and cost constraints. Existing production machinery was upgraded and new machinery was acquired some five years ago. The production machinery is not very sophisticated (no CNC machines for instance) but it is sufficient to manufacture with the required quality and at the required cost, or in other words, the cost structure is light and good enough to maintain an acceptable quality. The firm has also maintained uninterrupted efforts to keep abreast of new developments in the sector, by participating in international fairs, other important events, and in maintaining contacts with production engineers in customer firms. It is also through these actions that the firm publicises itself and searches for clients. Most of its clients are large textile firms and it exports components to Swiss manufacturers of textile equipment and textile firms. Nowadays high quality components represent 80% of production and manufacture of machinery represents only 20%. All decision-making is centralised in the owner. He performs managerial, technical and even administrative functions. The knowledge base of the firm derives from the knowledge base of the owner and from a few skilled workers trained on the job by the owner or his father and with no formal secondary education.

The average firm was established in 1970. It originated from a workshop dedicated to metallic structures for the construction sector. It started with the production of mechanical looms. The owner was a local capitalist with interests in other business asides from this factory. He was not therefore closely involved in the day to day management of the firm, which was done by its employees. The firm was quite successful, serving the regional market and at its peak its personnel numbered 90 people. When it was founded in 1970 it was equipped with up-to-date production equipment including automatic mechanical lathes. A foundry for iron and non-iron metals was also installed. Besides the looms it manufactured components and parts for textile machines.

The future of the firm was decisively affected by the fall of the regime in 1974. It was one of the firms that felt the socialist political contours of the agitated post-revolutionary period. In 1975 the owner was dispossessed from the firm and the workers took control of it. It was not nationalised, as others were, but it entered in a collective regime of ownership. This was the fate of the firms that belonged to important capitalists with dispersed interests, which was the case of the owner. Similar firms whose owner was also the manager were not subject to this fate. The firm entered into what was called “auto-management”. All decisions were taken in meetings that included all the workers. Decisions were extensively discussed between them and then submitted to vote. The firm operated under these conditions until 1986. The firm profited from its good regional position and from its knowledge base (not directly linked to the owner but to its employees, unlike other firms not belonging to large capitalist groups) in order to survive which it did with no excessive difficulty at least until early 1980s. It continued to manufacture mechanical looms for regional clients and to maintain the machines it had sold previously. These two main lines of activity sustained the firm.

In 1986 the firm was bought (from the expelled but still legal owner; the political situation had stabilised in the meantime) by a returned emigrant that had worked previously in the firm. This man worked for 15 years in SKF, Germany, as team leader on a production line manufacturing ball bearings. He had secondary level professional education acquired in Portugal before emigrating (his previous stay in the firm was in the context of the training period done at the end of the course). It is worthy to mention that this phenomena, i.e., productive investment by returned emigrants, is probably a very important phenomena in terms of explaining the industrialisation process in Portugal which we have already mentioned in another section of this study (cf. section on the Economic System) where it is mentioned the importance of capital investment in industry by returned emigrants from Brazil in the 19th century. Unfortunately this is a topic which has seldom been the object of systematic research. In this century the returned emigrants from Europe acquire an important dimension and perhaps not only and simply as the source of important money transfer (the most referred to impact in social or economic studies of emigrants). This transaction marked a discontinuity in the trajectory of the firm. The new owner brought with him new knowledge and a new style of management. Note, however, that the conditions in which he worked in Germany (in large and modern production lines of a firm supplying a large consumer market) were hardly replicated in the small factory in Portugal. In spite of his knowledge, based on on-the-job experience, the theoretical foundations of his technical knowledge were considerably limited. Those limitations would be important barriers for future attempts of product development resulting in excessive development time, excessive development costs and, sometimes, insurmountable technical bottlenecks. Another set of limitations refers to the inability to upgrade the production machinery. The firm avoided resorting to banks due to the high interest rates and due to the perception that the textile sector was going through a deep crisis with an uncertain future. It applies for state subsidies but without success.

Ultimately investment capital came from the family of the new owner, at an insignificant interest rate. This cheap capital is probably the main factor behind the survival of the firm.

Production of looms based on the same old principles was definitely abandoned because there was no demand for the machines. The textile firms that had old machines and could not acquire new ones were facing severe difficulties due to the technological obsolescence of the machines and its reflection in terms of production costs and quality of the product. The firm tried the modification and upgrading of existing machines still in operation, involving conversion from the principle of the “flying shuttle” to the principle of the “lance”, based on the imitation of looms that the owner saw abroad. But the costs of transforming a machine soon exceeded the cost of acquiring a new imported machine with the same principle. Another improvement introduced in the old machines was an electric circuit to control the colour of the thread. An individual not belonging to the firm made it. It was also based on the imitation and simplification of an existing version on the market. The decision of the firm to manufacture itself the circuit, instead of buying it out in the market was based on two orders of reasoning: one was that the cost of the circuits available in the market was too high and they wanted to reduce the costs, and hence the price of the loom, and the other was that it allowed the firm to carry out the maintenance later on if necessary, instead of replacing the entire circuit by another expensive one bought on the market. One can see that this description reveals the type of client base the firm was dealing with now, essentially characterised by small firms, technologically laggard and financially limited.

Due to the difficulties faced in the manufacture of looms, the firm relied more and more on the production of parts and components and the maintenance of machines. At first the firm was almost exclusively geared towards the textile sector but the transformations suffered by this sector after the mid-1980s had reflections in the client base of the firm. There were several factors at stake. The sector as a whole had acquired new production equipment based on technological know-how not available by the firm. There was also a large death rate among the firms of the sector affecting precisely those firms that still used the technology familiar to the firm. The large investment of the firm in moulds for replacement of parts was almost completely outdated. The technological change in the materials sector had also affected the demand for parts. Many of the components of looms were now made in materials other than steel or iron, the only materials for which the firm was prepared. Nevertheless, the manufacture of components and parts was rapidly becoming the activity that sustained the firm. The foundry, in spite of its technological backwardness, and because the firm still had some useful and specialised know-how in the manufacture of some non-ferrous parts, still made a profit. Because of the factors described above it now accepted and sought orders from any sector. However it faced competition from several sides; from unemployed metallurgic workers that were now self-employed after buying a second-hand lathe and making their own parts at home and from foreign firms that have other scale conditions.

After finally quitting the production or upgrading of looms and realising that the production of parts and components based on limited technological know-how and limited equipment machinery was a business prone to too much competition and risk, the firm tried to find an alternative machinery product line. Now its main goal, aside from its daily struggle to find orders for parts and components, was to find and define a niche on which to survive. In 1990-1991 after the expression of the need of a client the firm started to produce machines to stretch and cut tissue. Based again on the visual observation of existing machines or photos of machines that perform those functions the firm developed its own machine based on the mechanical principles it understood. Even so it had some difficulties in the design of some parts, particularly those that were related to the transmission and transformation of mechanical movement. Solution to those technical problems was only possible by resorting to the technical know-how of students of a technological centre. All electric motors and parts are bought out. The production of these machines now represents 20% of total sales. Occasionally it also manufactures specific one-off machines. Regional demand is reduced and the firm does not want or does not have the funds to engage in export activities. As such, its goal to find and define a market niche remains a priority.

The example above shows that the combination of a limited number of factors may result in significant improvements in the prospects of the firm (recall the innovative firm’s history). In spite of modest educational levels and knowledge capacities, commitment and investment differences in production machinery and search activities and a clear visionary strategic perspective gave fruit, and the point at which these decisions were made marked defining divergence points in the history of the firms.

11.5 FRAMA and PINHEIRO (Pair 4) – David and Goliath?

The following narrative compares the trajectories of two firms manufacturing woodworking machine tools, examining how the firms diverged in incorporating several factors and how those decisions were contingent upon their situations and how they were affected. Pair 4 is an example where limited doses of carefully chosen ingredients are sometimes crucial to the innovative performance of the firm ant its prospect of survival.

The innovative firm was founded in 1929, starting from the first moment with the manufacture of a complete product, namely pumps, initially entirely manually operated and afterwards, with petrol motors. The firm remained in this product line for ten years, gradually changing to the manufacture of machines for the woodworking sector, a sector that was quite strong in the region. It first started to manufacture table circular saws to cut planks and then large circular or straight saws to cut trunks. During the Second World War it proved difficult for the woodworking industrial sector to obtain imported machinery and the firm took advantage of this opportunity and started manufacturing its first complete machines for the sector. These machines were the so-called "charriots", after its French name, which were basically an apparatus to hold a trunk into whatever position is required and then cut it into planks with a large circular saw or with a straight blade. The manufacture of pumps was abandoned and the firm dedicated itself to the manufacture of this product. Initially, the firm provided machinery for the upstream part of the wood-working sector, i.e., for those factories that made the initial processing of the tree, and not for the downstream activities of joiners, carpenters and the like. Later, it diversified into this sub-sector.

The firm had, since its beginnings, the ability to get and import ideas and techniques from the producers of other countries (especially European, and later, from the United States), many of them under formal contracts, and it has continued to operate in much the same way until the present day, combining its own internal capabilities with the technological knowledge contracted or obtained abroad. The basic technology for the first charriots came from Italy, and was based on the construction of concrete columns (to support the trunk) and mechanical means of transmission of motion. Later, the whole apparatus was made in steel and iron. The firm had its own foundry and made its own moulds. Motion and cutting was still mechanically transmitted or controlled, and some operations had to be done manually with the help of mechanical devices, namely rolling the trunk over its support base.

The technology of the firm evolved slowly. Until the early 1960s, asides from changes in design, the only substantial development was the introduction of a mechanical device to deal with the rotational movement of the trunk. In the meantime, the firm began to diversify into other product lines, namely into lighter machinery to serve the downstream wood-working sub-sector. It also started to export to African countries (to the ex-Portuguese colonies; by then still under Portuguese control, so the term export is not completely adequate). By the mid-to-late 1960s, the first engineers came into place in the firm and a small number of personnel were allocated to design and development activities. The technology of the firm improved rapidly after that. Pneumatic and hydraulic components replaced the old mechanical devices. After a quick passage through electrical means of control, it adopted and implemented electronic devices in its machinery. Once again, the technological leap was accomplished by an enhancement of its internal capabilities through the absorption of external sources of technology acquired by formal procedures. It strengthened its internal capabilities with highly trained personnel and it reinforced its knowledge and technological base through formal contract agreements with external producers. In the early 1970s it started to export to the

Mahgreb and to some Asian countries under a licence from a German manufacturer (and using the same brand, which was its trick to open the export market doors). It was its first experience in foreign markets, other than the internal Portuguese overseas market. The electronic components were developed in co-operation with a French firm that designed and manufactured the circuits, which the firm then assembled. The exports to Europe started in the mid 1970s, first for Holland, then to Switzerland. The firm continued to steadily upgrade its products by improving its design, efficiency, reliability and overall quality, incorporating hydraulic or pneumatic components wherever possible and augmenting and perfecting the electronic control systems. This was accomplished by resorting to a variety of external sources, including domestic universities and foreign firms. Some of these contacts were based on a one-off contact, particularly those with people from the universities, and characterised by an informal nature. Generally, there was a person from a university that showed an interest in a particular problem faced by the firm and offered help. The firm continued to seek actively abroad for technological opportunities or for products that it could profitably manufacture and it made several formal contracts of a diverse nature. In the early 1980s more emphasis was put on the export market and in the mid 1980s it entered the U.S. market.

The 1970s was not only characterised by an improvement in the knowledge base of the firm but it was, in general, a period of great expansion. It embarked on serial production of machines, especially for the downstream woodworking sector, and considerable investments in plant and production machinery were made, alongside an increase in R&D personnel. This was accompanied by a general expansion in export markets and in the supporting commercialisation structure in those markets.

The product portfolio of the firm could now be divided in two main product lines: machines for the upstream sub-sector (essentially charriots), and machines for the downstream sub-sector whose diversity was reduced to planners, matchers, moulders and ripsaws (or machines combining these functions). These latest machines operated using the same principles and their construction was very similar. The choice of the portfolio reflected the serial production approach pursued by the firm.

However, the firm was to lose its competitiveness in serial production in the late 1980s. The loss of competitiveness was not caused by lack of development or improvements in their products. It has steadily improved its products in its two main product lines. Improved designs, more characteristics and capacity, more energy efficiency, were all improvements that have been introduced. Several operations were combined in one machine (allowing, for instance, a plank to be cut in all its six sides at the same time). Quality improvements in materials were continuously introduced and the machines were made more robust. Electronic systems for positioning and overall numerical control are now standard features of the machines. It introduced laser technology in the ripsaws and in the charriots for the precision alignment of the plank or trunk and its posterior precision cut. The charriots themselves are not sold separately now, but as an integral part of a complete system that encompasses all the production stages of a wood mill. In general, its products may not be the best in the market place but they are surely above average.

Their problems with serial production arose on the one hand from rapidly changing external factors, among them changing consumer requirements, which are now more sophisticated and specialised, which, in turn, require specialised machines and not standard ones (although the demand for standard machines may be rising in other non-European and non-American, less demanding markets in which the firm had problems in entering; they complain, for instance, that their European competitors enjoyed the political support of their respective governments in facilitating large-scale commercial arrangements with client markets, something that the Portuguese government did not do). Increased competition from the Asian NICs was another important factor that affected the firm. On the other hand, difficulties also arose from deficiencies in the firm's own production process, which was not fully optimised, or not as much as it should have been to compete in and with external markets. Some production practices were not modified (for instance, abandoning construction based on foundry and moulds in favour of soldering techniques, to avoid piling costs in immobilised moulds) and the firm did not engage in much sub-contracting, relying perhaps excessively on in-house production of much of the machine. Its efforts in the rationalisation of the production process came across several difficulties. It tried to implement a central computerised system to manage all aspects of production but the coexistence of two types of production modes (one based on serial production and another on single machines) complicated and reduced the efficiency of the system. However, a great deal of the production process is controlled in this way (e.g., stocks, materials, times, costs), but the system was not perfected. The environment in which the firm operates is also not very friendly to more demanding management techniques, such as JIT (Just-in-Time), due to repeated lack of observance by the suppliers. Even the internal habits and routines of workers proved difficult to change. The firm is now very committed to improve the efficiency of its production processes. It has hired consultants and commissioned studies to look at the problems and possible solutions.

The firm realised that, in order to survive, it had to rely more and more on batch production and the manufacture of tailor-made products. Consequently, its motto is now flexibility. Taking advantage of its production structure, it combined elements of mass production with elements of unit production. Working on a base model or a base structure, it introduced whatever requirements the customer asked for. For instance, regarding wood mill machinery, the firm elaborated a basic lay-out plan for the whole system that couples and integrates logically the machinery for the input of the raw material, the path management, the cutting process, the output of the finished product and the machines for the maintenance of the main machine. With the basic plan as a starting principle, it then adapts the machines according to the specific requirements of the customers. The same approach applies to the production of machines for joiners' workshops. Working within a basic model, it varies the performance and the characteristics of each machine according to customers' requirements. As a consequence, it developed a series of ancillary mechanisms that are sold as separate options that can be attached to the basic machine, as well as a large diversity of tools designed to meet a varied diversity of purposes.

The change of strategy from a serial mode of production to a batch mode of production was, however, a factor of disturbance to the firm because earlier investments in machinery and management systems were geared to mass production and not batch production. The firm is experiencing now some difficulty in changing and adapting to the new mode of production and its productivity has dropped. Just now it is still in this transition period, trying to take full advantage of its existing stock and adapting it to the present conditions.

The average firm in this pair has a different and more modest mix of factors but it nevertheless has enjoyed a not insignificant success. Its antecedent is a small blacksmith workshop founded in 1943, initially forging metallic structures of several kinds and later engaging in the production of car springs. The founder was a blue-collar worker who, apparently, worked with or for Eiffel in the construction of some bridges that were built in Portugal. This privilege must have surely been a matter of pride for the humble man and his offspring. His son and grandson, now in charge of the firm, do not allow such a fact to sink in oblivion, as they mentioned it with visible pride. The son of the founder was trained at a technical school and inherited the business of the father in 1960, pushing it in a somewhat different direction. It continued to fabricate structures but with a different material (stainless steel) and on a different basis (more production machinery than its predecessor) and targeted to a different type of client, the food industry.

Seven years later it started the production of machines for the woodworking sector, under growing regional demand for such machines. The machines were aimed at the downstream woodworking sub-sector, namely machines for joiners or carpenters' workshops. The knowledge to build the machines came from a coalition between the owner's formal technical training and ability, an employee that was particularly skilful in the craft and in design, and another employee that proved to be rather adept in administrative and organisational tasks. This combination of skills and the team spirit that permeated the group was quite successful, so much so that in 1973 the owner offered a part of the company stock to its two former employees (15% to each one). The skill, dexterity and tinkering of the two technical men are the main factor behind the growth of the firm, underpinned by a neat and simple organisational structure. The firm enjoyed successive expansion periods and the early 1970s saw significant technological improvements in their products, which were essentially manual or mechanical. It adopted a new concept for its basic mechanical devices and it introduced pneumatic and hydraulic devices as well as electric means of control. The firm also delineated quite clearly its target clients (manufactures of wood furniture) and was very open to suggestions and requirements from them.

It has continued to operate in this way ever since. The son of the owner replaced the partner who had been in charge of the administrative tasks. The son has no formal technical training, although he completed his secondary education. The firm admitted a university dropout student who is now allocated to design and development of products, working together with the former employee who is the main contributor to the design activities of the firm. The production directors have formal secondary technical training. The firm has complemented an apparent deficiency in its knowledge base by resorting to hired consultant engineers. They are thinking about recruiting a production engineer, which reflects the concern of the firm with organisation and efficiency matters. Since the late 1980s it has sent some of their workers to attend short professional courses at technical schools. The areas of training include pneumatics, hydraulics, electricity and soldering. In this way they have managed to upgrade their skills and their knowledge base regularly, and although it is not very sophisticated, it has not become static. Learning processes continue. They also spend considerable efforts scanning the market in similar products and getting some ideas to improve their own.

The strengths of the firm seem to derive from the following sets of factors. First, its flexibility in responding to user's requirements and in maintaining a neat and slim structure, avoiding the creation of heavy structures. Technologically, the products are not ambitious, but they are also sufficiently sophisticated, especially in mechanical terms, so as to satisfy their customers. The products are of good quality, with attractive and elegant designs and very easy to operate, although their range of operation is frequently rather limited. The firm has been very creative in identifying market niches in products not available in the Portuguese market, and has designed several machines that fulfilled the gap, thus allowing the woodworking workshops to substitute with machinery previously labour intensive processes. The firm also identified clearly their target market, usually small or small-medium workshops that do not require or cannot afford very sophisticated or costly machinery. It makes considerable efforts in keeping abreast of the difficulties, requirements and expectations of its clients and in providing swift and efficient after-sales services (a technical services department was set-up for this purpose, one of the few additional structures created by the firm).

Investment in production machinery is enough to maintain a certain degree of quality and aimed at optimising capacity utilisation. It does not possess CNC machines but some of the machines are semi-automated and provide a reasonable degree of precision. The work flow is devised efficiently with the support of a simple computer program to keep track of costs and times. The shop floor is clean and ample, with an well-organised layout and it provides a pleasant working place. Unlike its innovative pair the firm has never engaged in serial production. It appreciates the flexibility it has and wants to keep it that way.

The weak points in the firm are related to its excessive dependency on the dexterity and creativity of its chief designer, the former employee now partner, and the tinkering and mechanical ability of the owner. As mentioned earlier the firm has admitted only one person to design activities, a university trained (but not graduated) designer who introduced computer assisted design techniques to the firm. The deficiencies in the mechanical knowledge base are dealt with by resorting to consultants, a practice that is cost-effective and enhances the so cherished flexibility, but that in the long run may impair the firm in acquiring and building up its own technological and absorptive capacity. The threat is all the more visible as these two key figures in the firm are now getting older and close to retirement age. The son of the founder is not a mechanical man and thus not a substitute for the knowledge embodied in those individuals. The future of the firm is dependent on the vision and foresight of the heir to acknowledge and remedy this deficiency. The capacity to effect the change may be curtailed by a general mental attitude that still prevails in many industrialists that is related to the way they regard qualified engineers as being too much theoretically oriented and unable to deal with the practicalities of the craft. This prejudice is probably rooted in the historical social divide that permeated Portuguese society for so long, and the clash between two different ways of approaching the production and manufacturing process. There are also problems related to questions of the balance of power that the introduction of highly skilled personnel would inevitably bring to the firm.

Whatever the case, the firm has enjoyed until now considerable success in its endeavours. It has moved beyond its regional boundaries of action, although this is still an important market, and it commercialises its products nation-wide. It has even exported some of its production (around 10%) in the last couple of years to Spain, Canada, the Dominican Republic and United States (in order of importance) and it has participated in some international trade fairs. Its longing for flexibility and the dependence of its clients on the construction business cycles are behind its reasoning for avoiding the internalisation of commercial structures or the elaboration of strict or quantified formal planning procedures, which however does not prevent it, as mentioned, from having a very clear perspective of what its business is.

What are the selection mechanisms involved in this example? The two firms cannot be strictly compared because the innovative firm manufactures products (charriots) that the other does not. However they can be compared on the other product line. Curiously enough, the average firm seems to be going along with fewer problems than is the innovative firm. The reason for that lies in the unsuccessful attempt that the innovative firm made to engage in serial production, which in itself was due to deficiencies in production organisation methods, insufficient investment and training in more advanced manufacturing techniques and perhaps a certain failure in assessing and evaluating the direction that the (customer) sector was taking. If, however, it is able to surpass this problematic transitional period and make the appropriate decisions, it may be able to regain its feet again. The obsession of the average firm with flexibility and slim structures has helped the firm get through tougher periods without any particular difficulty. However, if the obsession is carried too far it may prove a liability in the future, instead of an asset.

It seems apparent that the two firms operate for different sections of the environment, regarding their common product lines, or to different markets altogether, when export markets are considered, although it seems that the gap was larger than it is now. The characteristics of the products reflect the different requirements of the environments.

The innovative firm produces a relatively small portfolio of very high quality and sophisticated machines, with the capacity to process high quantities of material, geared to relatively large workshops demanding high precision features. Its strength is its own technological capacity coupled with the ability to permanently scan and absorb technological novelties through diverse means including formal contract arrangements.

The average firm produces a somewhat broader range of lighter equipment, relatively cheaply, performing a limited range of operations with a lower degree of precision, geared to smaller workshops and less demanding customers. Other helping factors that have sustained the firm are its after sales services and its very close contacts with customers, its flexibility, a slimmed and cost effective structure, and its creativity in devising new machines unavailable in the Portuguese market to perform sometimes simple operations but which are a source of great value-added for the workshops that employ them.

11.6 MECANO-TEXTIL and ACL (Pair 5) – more troubled manufacturers of textile machinery

The firms that constitute pair number 5 provide an additional digression into the difficulties experienced by firms manufacturing equipment for the textile sector, and shows how they reacted to the threats to their business.

The story of the average firm describes the declining path of a once successful firm. Two engineers founded it in 1943, one of them specialised in the manufacturing of textile machinery. He came from a Spanish region whose industrial specialisation was also in the textile sector. The other engineer acted as the commercial partner and did not gave any special technical input. Initially the firm operated under licence from a Spanish company and it acted more as an auxiliary arm of another firm that imported textile machinery, providing technical assistance, maintenance, repair and assembling.

In 1963, its activity became autonomous and it started its own production, manufacturing whole machines, under a new licence agreement from a Swiss firm. The firm specialised in two main product lines, although it occasionally manufactured other types of equipment (but with no real significance for the revenue of the firm). The two main products or product lines were fibre blenders and ring spinning frames.

The firm enjoyed considerable success and growth. It was practically the only firm in Portuguese territory manufacturing these kinds of machines and it did not operate under complete monopolistic conditions because it faced external competition from imported machinery. Tariff and political barriers to such imports were intermittent and although they gave the firm some sort of protection, their discontinuous nature made them, for practical purposes, rather ineffective as a protection mechanism. By the end of the 1970s, almost all large textile firms were its clients, at which time the firm began to manufacture its own products, ceasing its licence agreements.

The firm invested in its own R&D capabilities, maintaining a separate department with several mechanical engineers designing and developing its products. It introduced several improvements in the machines. It switched from mechanical systems of control to electronic systems of control. It increased the number of spindles and the spindle speed through improvements in the electric components of the machine. It made the machine less heavy and bulky. It introduced several ergonomic designs to ease its operation and increase safety. It automated several of its functions, increasing the flexibility of the machine.

The firm remained relatively competitive during the early 1980s but its position in the market started to erode, as the economy began to open up and to abolish whatever barriers there were to imports of machinery. At this stage the firm employed 140 people and it had a relatively sophisticated capital stock that would be subject to additional upgrading during the second half of the 1980s when it acquired automated machinery. The timing of this investment was perhaps not very appropriate, or not properly accompanied by other measures as the firm was beginning to lose its market share.

Given the size the firm had reached, its apparent commitment to internal R&D activities and the type of machines it produced, the firm made certain decisions that were strangely at odds with its situation and may explain its demise.

Firstly, the firm never had any formal planning procedure, which, given its size (above 100 employees), would be reasonable to expect. This necessity was even more compelling as it never developed into a cohesive familiar-type structure that has the potential to provide a clear strategic perspective even if not written down. The equity of the firm changed hands several times and the distribution of capital was never decisively skewed towards a single hand. Maybe it was because of this constant turnover that the firm was unable to find a clear direction in face of the difficulties it faced. Whatever the causal direction between strategy, planning activities and ownership structure, the truth of the matter was that the attitude of the firm was basically reduced to manufacturing the machines it traditionally had produced to serve the clients it traditionally had served.

The lack of sufficient planning extended to the production process and to training activities. Efficient production methods and processes were severely constrained by ad-hoc addition of equipment and an ill thought out layout and expansion scheme. Technical training of workers was almost exclusively done in-house and only sporadically in technical centres. It had a considerable (negative) impact on the adoption by the firm of upgraded production techniques and on the quality of the products.

In addition to that, or because of that, the firm never did embark on export activities, which would also be reasonable to expect given its size and the level of investment in R&D activities. It came out with timid attempts to do so, but they were short-lived, sporadic and not well organised or guided by any explicit strategic decision.

It did not invest enough resources in R&D activities in face of the new competition that open markets were fostering. Imported machinery using the same basic technology was more reliable, faster and more automated than the machines offered by the firm. At the same time, spinning frames based on different technological principles and trajectories (vacuum spinning) were increasingly available in the market. These machines, asides from overcoming the problem of breaks in the thread due to the speed of the spindle, combined several stages of successive spinning into thinner threads into one operation.

The combination of all these factors compounded the problems of the firm. They were becoming technologically laggard, losing domestic clients, not searching for new ones, and decreasing R&D investments due to financial problems. The firm was also excessively closed and inward looking, and engaged in very few relationships with other technological centres or firms. Production of components for its ex-licensors, one of the few relationships it still had, and maintenance or upgrading of its old machines became an increasingly important component of its revenue. Search for new alternatives was not pursued. In fact, and surprisingly, it rejected some offers from car manufacturers to produce a different sort of product. The offers were very significant and could have sustained the firm for several years. To make things worse, some of the R&D engineers left the firm shortly after that and founded a firm that took up the orders from the car manufacturer. The situation gradually deteriorated, successive divestment took place, and the firm downsized its work force and its R&D personnel. At presently, the firm has no R&D activities and its activities are practically reduced to maintenance of its old machines (upgrading of old machines is now seen as uneconomical by client firms). The firm is in serious financial problems and its most likely future is to close down.

The innovative firm in this pair portrays a story of flexibility, high capacity to adapt to new circumstances and quicksightedness. It is not strictly comparable to its pair because the products are not identical, although directed to the same industrial user group, the textile sector. Nevertheless the problems faced by mechanical firms supplying the textile sector, whatever their product line was, seem to be identical, insofar as all firms experienced increased difficulties after the mid 1960s due to external competition and compounded by the lack of an industrial policy to support and defend their interests, or stimulate their activity. In this respect, it is interesting to compare the means used by each firm to get out of the difficult situation they were in.

We have seen that the latter firm chose to continue the manufacture of its traditional product but failed to invest sufficiently or adequately not only in its core development activities but also in ancillary activities such as production, training and marketing. It also failed to recognise the danger it was in and lacked the ability and the flexibility to adapt and grab new opportunities and change its product line.

The course followed by the innovative firm was in almost every respect a sharp contrast. The firm was founded in 1924 by the grandfather of the actual owner. Before starting his firm the founder was a loom maintenance technician. His educational level was at the primary level and all the know-how and skills that he used in the manufacture of looms, the initial and sole product of the firm, were acquired on that job. It started as a small workshop but it soon grew. It possessed its own foundry. The production of looms lasted for a long time. In 1944 two sons inherited the firm and gave continuity to its production. Both were trained in secondary technical schools. The looms were mechanical and were improved steadily over time. The sources of ideas and improvements came basically from the imitation or copy of other machines. The firm enjoyed continued growth until it reached its peak in 1965, with 120 employees, when it then started to be strongly affected by external competition from technologically superior machines. It soon realised that it was unable to compete with the imported technology and started manufacturing hydraulic presses. By this time the sons of the owners (and grandsons of the founders) began to take control of the firm, and in 1970 the inheritance was completed. Both were mechanical engineers trained at university level. One of the brothers was particularly interested in electronics and later founded his own electronics firm. The combination of their respective interests and expertise later proved to be an important factor in the evolution of the firm.

In 1973 the manufacture of looms was discontinued, as well as construction based on foundry and casting. It switched to soldering construction. Its main product, hydraulic presses, was also subject to a significant technological re-conversion. At the same time it received an important order from a large firm in the wood processing industry. This firm wanted a loading and transport system to carry and store large planks. This order marked another turning point in the firm and it contributed to the definition of one of its later lines of specialisation, namely the production of lifting machinery and related products (work platforms and hydraulic dock levellers) to equip warehouses. The firm also specialised in hydraulic components. The product switch was further evidence of the capacity and speed of adaptation of the firm in the face of difficulties. The difficulties in this case arose from the fact that they were facing increased competition from hydraulic press manufacturers. Many firms were now producing this type of equipment. The firm was even sidelined by a former partner, a firm that co-operated in the development of the press. This second firm was larger and had a consolidated commercialisation structure. It was able to manufacture the press at a lower cost, sell it at lower prices and distributed it to a wider range of clients. It also independently introduced additional improvements to the press. Our firm was quick to realise that its chances to compete were getting thinner, and the order to manufacture a loading and transport system made it realise how few firms in the Portuguese market were in that niche. Thus, it decisively embraced this opportunity.

Again based on imitation and copy, but also on their own technological capabilities, the two brothers started to develop that new product line, consisting mainly of hydraulic column lifts for warehouses, dock levellers, also for warehouses, and work platforms for several uses. During the early and following years they served essentially large firms, but later included in their list of clients a series of smaller firms. The production of hydraulic presses did not cease immediately but its significance decreased substantially, until it finally was abandoned.

The products were subject to gradual improvements over time, such as the inclusion of better security systems, quality improvements in materials and finishing and development of hydraulic and electronic controls.

The firm was actively engaged in co-operation with several entities. It had a well established and long lasting relationship with an important manufacturer of machine tools, it invited the collaboration of several engineers to resolve particular problems, it maintained relationships with a technological centre and was keen to accept university undergraduates doing their curricular industrial training period. The firm has maintained this pattern of co-operation.

The firm consistently upgraded its production equipment, with a concern for quality, and improved its organisational routines, with a concern for costs and flexibility.

In the mid 1980s, the experience and knowledge derived from their earlier development efforts of hydraulic and electronic controls for the lifting gear opened the way for a new project in which the two brothers would combine their respective skills. The project resulted in the development of a new control valve, or more accurately a group of hydraulic valves to regulate fluid flows, which combined principles of hydraulics and electronics. The product was patented in 1994 and it is now an important source of revenue to the firm.

Now, the firm employs three engineers and has a department exclusively dedicated to design and development activities, using the latest computerised design techniques. It has continued to upgrade its production machinery and presently has two CNC lathes and one CNC machining centre. Asides from the product lines described above, which are being diversified to include lifting gear for disabled people, it also produces precision components for German firms on a subcontract basis. It exports 5% of its production (in terms of sales).

It established an office and commercial department to serve the second half of the national market and great attention is paid to after-sales services. It has its own quality control department. Production organisation is being restructured and increasingly subject to computerised techniques. The firm is now looking for expertise in the area of production engineering so that a properly trained individual can perform the management function.

To summarise, we can say that in this case there is progressive divestment in R&D activities on the part of the average firm, which initially performed rather well, driven by a previous position of near-monopoly and by the relative isolation of the firm in terms of contacts with outside sources of knowledge. In spite of possessing good human resources it did not take advantage of them, which was one indication of difficulties in terms of management and in terms of strategic specification of objectives and goals for the firm when products from abroad gradually outperformed their own products and eroded its competitive client base. The firm did not invest sufficiently in R&D either because it was unable to perceive the threat or because it could not or was incapable of finding alternatives.

The innovative firm reacted flexibly and quickly to threats and changed and qualitatively downsized its output (in the sense that it started to produce parts instead of entire machines) but without disregarding improvements and development work. It continued, in fact, to bet on highly trained personnel and to allocate personnel solely to development work, although in a modest way. Unlike the former, the later firm was able to find a response to an environment that become more international and demanding.

11.7 MAQUISIS and SERI (Pair 6) – the new generation

The two firms in pair 6, which produce metal working machine-tools, are both very young firms, and they provide an interesting example of a new generation of firms that are making their way. The innovative firm was founded in 1987 and the average firm in 1989. Both possess and started with a high proportion of highly educated personnel, namely mechanical engineers. Both owners are university lecturers and both worked previously in other machine-tool manufacturers. Thus, since their beginnings the firms possess a solid, updated scientific and technological backlog.

Their modus operandi is also very similar. The firms specialise essentially in design, project and assembly, to which they give their utmost attention and concentration. Every possible standard component that can be bought out in the market is so acquired. They reserve for themselves the manufacture of the most sensitive or non-standard parts of the machines and the integration of the components. For instance, the innovative firm buys in all hydraulic and pneumatic components (this is, in fact, a feature common to almost all 19 firms in the sample), all machining units, all small and medium components, all electronic components, the CNC kits and the programmable robots. The manufacturing activities of the firm are restricted to the structural core of the machine, the outer metal shield and the precision binding components. The tools are either selected from standard ones existing in the market, or, if they are not available, are designed by the firm and ordered out. It also makes the software for the integration of the CNC. Overall, in terms of value added, the internal production is around 40%.

The average firm is even more drastic, reducing that figure to 10%. This is perhaps due to the more demanding requirements faced by the innovative firm and the consequent inability to find in the market components that fit those requirements. The type of production machinery each firm possesses seems to substantiate this argument. The innovative firm has more advanced and sophisticated production machinery (e.g., numerical control milling machines) than the average firm.

On the other hand, this small number is the reflection of a conscious commitment to out-source the maximum possible amount of parts and components. The pattern of out-sourcing of the average firm is similar to that of the innovative firm, and unlike its pair it does not develop the software that is also contracted out.

Internally, both firms function as close-knit teams. Every person is considered important and communication flows naturally with no barriers. Intensive encouraging of the employees to do their best and to help sort out problems is common practice in both firms. Workers on the shop-floor are not allocated to a specific task and rotation between tasks occurs frequently. The educational level of the workers is comparatively high (all were trained in technical schools and some have completed their twelfth year of secondary education). The recruitment of engineers is very selective. They have not only to possess the scientific and technological knowledge and ability deemed necessary for the job, but their psychological profile must also reflect high degrees of adaptability, flexibility and capacity to work in a team.

In view of all these similarities, what then differentiates these firms? One of the factors is external and it is perfectly captured in a response from the average firm. When answering the question of why its products were not more sophisticated, it replied that it was because the customers did not want very sophisticated products. It added that, technologically, the firm had all the capacity to build whatever machine they wanted. This may seem presumptuous but it is probably close to the truth.

In fact, there were dissimilarities between the type of customers the firms served. The customers of the average firm were mainly firms manufacturing water taps and connected or similar products, such as joints, sockets, tubes, etc. Other clients included cutlery manufacturers, bicycle manufacturers and domestic appliance manufacturers. Occasionally, it sold some machines to manufacturers of car components. The pattern of clients of the innovative firm was almost a mirror image of the pattern of the average firm. The main client was a car manufacturer (a subsidiary of a multinational), whose orders were, actually, the very reason for the creation of the firm. Other clients included a series of car component manufacturers and, occasionally, manufacturers of cutlery. Therefore, the pattern of customer demand was, apparently, an important determinant of the degree of innovativeness of the firms. The car and car components manufacturers are sectors that demand higher levels of quality and precision, have higher levels of capital expenditure and are willing to pay much better than the other mentioned sectors (in general terms). As a consequence, machines built by the innovative firm can be much more sophisticated and can cost as much as two hundred and sixty thousand pounds against an average price of fifty to sixty thousand pounds for the machines of the average firm.

However, internal factors must also be accounted for. The innovative firm succeeded very early in its lifetime in defining clearly and unambiguously its product specialisation and made that decision with great determination. It is specialised in what it calls shred-tear machines, it manufactures only machines based on that principle of operation and its client base is very restricted. Its product design and development approach is characterised by a systemic nature whereby special attention is given to the integration of the operation that the machine performs into the overall production process of the client firm. In contrast, the products of the average firm are not specialised in the strict sense mentioned above and the range of clients it serves is much broader and more diversified. The machines serve a wider range of purposes and operate on wider principles. The machines manufactured by the firm include lathes and machining centres, but also drilling and tapping machines, saw machines, manipulation systems and bending machines. The dispersion of skills and knowledge required for switching between the disparate operating principles of the machines may not have good effects in terms of the cumulative processes involved in building their tacit knowledge. It may, however, have positive effects if the firm is able to integrate such diversity in a fruitful and innovative way, as seems to be the case regarding their recent plans for a new product. Anyway, the firm is now actively engaged in defining in a much clearer and narrow way its line of business. It has commissioned an in-depth market research study to try to identify a product and a sector that would allow the firm to achieve a greater degree of specialisation. One of the alternatives that it is considering at the moment is to produce a completely automated machine to manufacture aluminium windows frames. The machine would perform all the basic operations of sawing, milling, grinding and bending, and would also load and unload automatically all the raw material and finished products. Programming would allow the machine to change all the dimensions of the frames (length, width, depth) and even their form (linear or curved) and ingrained patterns.

It is curious to note that the target sector of this new product remains closely related to the building sector, as it is the case with their main clients (manufacturers of water taps). It shows the constraints firms face that are determined by their social spheres of action and influence, and the weight of previous working experience. The same argument also applies to the innovative firm. In this sense, social network aspects may eventually bind the firms to specific actors and artefacts and influence their innovative performance. Each firm was quite aware of the activities of the other but even when both firms moved in higher levels of social networks, subtle differences and divergence processes still apply. Not only were the owners' previous industrial experience and personal contacts were acquired in different firms manufacturing different products for different industrial sectors, but they are also attached to different universities that differ in their ethos, objectives, capacity, specialisation and established relationships with outside social groups or interests.

11.8 SERSAN and PRENSARTE (Pair 7) – there is room for all

Sersan, the average firm in the pair, was born out of a mechanics workshop that was created in 1975 by four brothers (plus two employees). Its current name was not its first. The name of the firm was altered in 1986 and coincided with the change of activity of the firm, i.e., it coincided with the beginning of manufacture of machinery for the cork industry. It also coincided with the entry of another brother to the company and the equal redistribution of equity, previously concentrated in only one, by all the five brothers. Three of them were ex-employees of firms that manufactured machines for the cork industry. Another worked in a ceramics manufacturer with functions related to electrical maintenance and repair, an activity for which he was qualified by virtue of his secondary professional education in electricity and engineering. Two other brothers were also educated at secondary professional level. The rest of the personnel had only four years of elementary education and were trained while working, in an apprenticeship regime. Personnel are hired at a very early age (16 years) to avoid personnel with other types of training and then trained internally. Many of the employees have worked only for this firm that tries to maintain a good, although perhaps paternalistic, working environment.

The firm started with the production of manual drilling machines which were used to make cork stops. The machine was extremely simple, almost primitive. It had simply a superstructure supporting a moving part with the cutting tool that was controlled by a pedal moved with the foot. The physical principle behind the machine is torque. The operator would hold a small plank of cork, choose subjectively the best part (in terms of texture and in terms of optimisation of the plank) to cut and then would manually position the plank and press down the pedal, and the movement was transmitted through moving metal parts to the tool. No additional sophistication was present such as for instance, safety devices to avoid hand injury, which apparently was not uncommon. Such a machine lets us guess the worst kind of Taylorist mode of production the clients of this firm were engaged in. Some untidy workshops with a couple of rows of these machines operated 8 or more hours a day by badly paid, uneducated and unqualified personnel, producing day after day always the same few sizes of cork stops, later sold to a distributor which would buy all the production of a lot of similar firms. These machines are still made today, essentially unaltered, only with the addition of an electric motor to substitute the pedal.

In addition to the drilling machines the firm also manufactures a series of machines to finish the cork stops, namely: a machine to cut the stops in standard lengths and to polish the top, a machine that smoothes off the lateral part of the stop, a machine that washes and treats chemically the stops, and a machine that engraves a drawing in the stops. All these machines are also quite simple and operate by mechanical principles with electric motors as the power force.

Recently the firm has secured the collaboration of another (very) small firm in the field of electronics (owned and managed by an electronic engineer) and has engaged in other product lines which are more sophisticated. They started to manufacture transport and feeding systems, which aside from the usual mechanical components were complemented by automatic mechanisms that at the end of the transport line guide the cork stops to basket reservoirs. Additionally they have also installed a system that controls the filling of those baskets. The system is based on a set of photo-diodes placed at two required positions (signalling a minimum and a maximum). All the electronic components and circuits are designed and manufactured by the other firm. Our firm does the mechanical part and the electrical part. Their most recent collaborative product, based on the same technologies, is a cork stop counter machine. The machine consists of a container in the form of a funnel where the stops are placed at the bottom of which there is a moving roller that forces the stops to enter in an orderly manner and by the force of gravity into four channels. At the end of each channel is a photo-diode that counts each passing stop and then sends the signals to a microprocessor that allows three operations to be programmed: the quantity of stops that must fill each sack, the number of sacks that can be filled and whether it works in automatic or manual. As in the case of the transport systems, the mechanical and electric part are made in the firm and all the hardware and software related to the electronic components is made by the other firm. They have sold only a few of such machines.

In spite of the relative simplicity of the products manufactured by this firm their business is apparently going well. Decision making relative to global aspects of the firm is done by all the partners/brothers and additionally each one has a stronger say in particular functions/technologies. For instance, one of the brothers is in charge of the mechanical part, another of the electric part, another of the marketing and within each function (for instance mechanical) there are sub-levels on which one of the brothers may be more knowledgeable than another. However, perfect delimitation of competencies does not exist (except perhaps as concerns the marketing function) and every decision is done with consultation and participated in by all the brothers (recall that they all have the same basic vocational training and three of them worked with manufacturers of similar equipment). Production is based on teamwork. Workers may work on more than one function or one machine although they may be more apt to work with a specific machine/function.

The firm automated its administrative tasks but production operations are managed on a day-by-day basis. Cost control is helped by a simple form of analytical accounting but essentially by the subjective perception and comparison of variation in costs. Based on this perception, particularly on the realisation that component prices are becoming less than the cost of manufacturing in-house the component, the firm is sliding more and more towards manufacture based on assembly of parts and less and less on in-house manufacture and assembly. The cost of replacing production machinery is also a non-negligible factor in the making of this decision. The existing production machinery is quite old (10-20 years) and it consists only of mechanical non-automatic machines, with no improvements whatsoever. The exception is a recently acquired painting cabin. The firm has also started to use CAD very recently.

The firm tried recently to abide by the new EEC directive concerning machines but it soon realised that it did not have the necessary technological know-how to do that. It resorted to a technological centre but it found the price too high and did not proceed further with the process. This event tells a lot about the limitations of the firm relative to more demanding technological or technical conditions. The machines manufactured by the firm are simple (even the electronic circuits are relatively simple) and they will remain simple unless the firm upgrades its knowledge base. Products that will involve more mechanically sophisticated movements are presently out of reach of the firm.

The firm is very customer-conscious and its relatively comfortable position owes probably a lot to this behaviour. The firm’s motto is “every client is important”, “each client is a friend”, and “if a client ceases being a friend it will cease sooner or later to be a client”. This attitude is behind the extreme importance that the firm attributes to after sales service. We can say that the position and strategy of the firm relies heavily on the degree of after sale satisfaction that the firm provides to its client. Since its products are not technologically demanding and can be easily made by any existing or entrant firm there is an effort to secure customer fidelity to the firm by means of its service so as to secure future orders.

The firm supplies equipment goods to a sector that is greatly concentrated on the surrounding district. The cork itself originates from a tree that is cultivated in the south of the country but the transformation of the cork is done in the North, and specifically in that district. The cork is subject to various processes of transformation but the cork stops are an important final product. The sector is made of a multitude of small firms working under simplistic conditions and making simple products like stops and a few large producers of products other than cork stops with a much greater value added and requiring more sophisticated transformation processes (such as flooring or specialised intermediary products for other industrial sectors). Some of these large producers worked previously under licence and have gradually built their own expertise. Consequently there is a large demand for simple machines that the firm is able to satisfy. In addition to this, competition is reduced. There are only a handful of producers of machines for this industry and, at least for the time being, they do not stumble on each other. Very recently, equipment goods for the cork sector were either imported from Spain or Italy or manufactured by producers of machine tools for woodworking with sometimes not very good results (due to the unsatisfactory adaptation of the existing machines to the different properties and characteristics of the material). This firm is thus for the time being occupying a niche previously almost vacant. Its client base is huge (around 400 firms) but constituted almost (if not completely) exclusively by small firms of the type described above. None of them is an outstanding client that absorbs the majority or a substantial part of its production. It also exports some of its production (10 to 20%) to Spain and Italy, presumably to the same type of clients it has in the district.

The innovative firm was founded in 1983, producing hydraulic presses and repairing machinery in general. After a brief experience manufacturing also a machine to make aluminium frames for windows and doors it soon found its specialised niche. In 1985 it dedicated itself exclusively to the manufacturing of machines for the cork industry. It was founded by three partners, one of whom later left. One of the partners is a mechanical engineer and the other has a professional qualification at medium level (secondary level plus one year plus training). Both worked in the manufacture of equipment goods (one of which produced presses) before starting their own firm.

The firm started producing relatively sophisticated equipment based on mechanical, electromechanical, pneumatic and hydraulic principles. It manufactured several kinds of machines for several stages of the production process including transport and feeding systems. There have been considerable improvements in terms of automation and special characteristics. The products of the firm include an automatic saw to produce cork tiles, an automatic machine to smooth and finish the cork tiles, a machine that selects cork grains, automatic transport systems, among others. Their most important development has been in the introduction of optics (laser) technology into the machines. One of the machines makes the selection of cork stops tops optically and separates them according to its quality level. Another is a drilling machine to produce cork stops. It “looks” at the cork plank, analyses its texture and elaborates a plan that simultaneously takes into consideration the quality of the material it analyses and the optimisation of the plank in order to reduce wastage. The entire process is automatic. The operator only puts the plank in position and then the machine takes care of the rest, i.e., the product ejected by the machine is ready for the next production stage. Quality parameters, among a series of other parameters, are programmable.

The firm does not make the optical components of these two machines. They are a result of a collaboration agreement with another firm. The firm has established a formal agreement with an Italian firm that develops and manufactures the optical devices and the accompanying electronic circuits and software (some of the software was developed by our firm). The agreement made with the Italian firm is quite formal and involves market conditions, namely, the firm is not allowed to commercialise the machines developed jointly by the two firms in Italy and the Italian firm does not commercialise the machines in Portugal. It is curious to note the similarity of strategies, at least at this level, pursued by the average and the innovative firm. However, there is a qualitative difference between the technological level of the partners of each firm. While the partner in the case of the average firm consists essentially of an electronic engineer, the partner of the innovative firm is a medium sized establishment with a significant level of R&D activities. The complexity and the technology of the products of each partner are also qualitatively different.

The technological level of these machines is a long way from the level of the drilling machines produced by the average firm and described above. The complexity of functions and the overall quality of the machines are at a superior level relative to the average firm. The firm has, for instance, no difficulties in terms of calculus knowledge that the other is unable to cope with. It also complains about the shortage of skilled workers, a complain that is recurrent amongst the firms of the innovative group.

Administrative tasks are automated as well as cost and time control but not production, nor there is any integration system with downstream or upstream functions in place. However the managers feel that production organisation and operations should also be subject to a systematisation process. Teamwork prevails also in this firm, without a visible paternalistic character (although that does not mean it is absent) and many of the workers were also trained in this firm but their previous qualification level is much higher than that of the workers in the average firm. Half of the workers have secondary level qualifications. The firm also sends its workers to outside training courses. Approximately half of the workers have benefited from this.

Design has been made using CAD since 1985 (i.e., since they started production of machines for the cork industry). Production apparatus is also better than in its counterpart firm. Although the basic equipment is mechanical, some machines (namely all the milling machines) were subjected to improvements (e.g., electronic/digital control of position/coordinates) and they are going to introduce the same device in all the lathes. There are plans to buy a CNC lathe and a machining centre.

The customer base of this firm is much more restricted than the average firm's base, and since its inception it has served the largest and most important firms of the cork sector, and specifically the main national groups (which are also physically located in the same district referred to above). Its machines have a price that excludes a lot of firms from the cork sector from being potential customers of this firm. In any case, scale considerations would also prevent those firms from buying such machines that are designed according to the specifications of large manufacturers of cork products. This firm also scores high in its relationships and after sales services with customers, but its strategy is not only exclusively based on that. The other important component is product development along the lines of increasing automation and quality. Based on that strategy they have started to export recently and are betting strongly on the export market to increase sales.

The average firm in this pair manufactures extremely simple machine-tools for the cork industry and it is able do so because it finds that its products are in demand from a multitude of small firms processing cork (making cork stoppers). Their best machines required improvements based on relatively mature technologies and simple designs, althoug it required outside assistance. The selection criterion is not based on advanced technology products. One wonders whether if it eventually tried or if it were able to upgrade too much its products, and presumably charge higher prices, it would not then be confronted with a very different and probably unfavourable demand curve from that sub-environment. On the other hand, its innovative pair operates in another section of the environment comprised by large firms. The machine-tools produced by these firms are mechanically much more sophisticated and of greater reliability and quality and incorporate sophisticated electronic and optical devices. These firms do not compete for the same clients and the survival or growth of one of them does not affect the survival or growth of the other, as long as the environment remains split, and as long as each firm does not invade the domain of the other.

11.9 DIARROCA and ADIRA (Pair 8) – worlds apart

The average firm was established in 1979. Its owner was a returned emigrant from Venezuela where he worked on metallurgical factories as a machine operator. When he returned to Portugal he went to work for a then renowned manufacturer of machine tools. He stayed there for six years as a supervisor and then established his own firm with a partner who left soon after. He is now the sole owner and manager.

The educational level of the owner is at the elementary level plus a course on technical drawing of machines that he took in Venezuela. The qualifications of all the (six) employees are also at the elementary level. Some of them also worked in the same manufacturer of machine-tools, which, it should be mentioned, closed down recently. The premises of the firm are very small, not exceeding 100 square meters and the machines, the workers and everything in general is crowded inside the small place. The working conditions, as one might guess, are quite unsatisfactory. This is something that strikes one out at first sight. It was the firm with the worst working conditions of all the firms in the sample.

The firm started with the production of components and metallic structures and also machines. Now it only manufactures components, and this is the only product line of the above mentioned three that has been consistent and regular. The production of machines was pursued during the first years of existence of the firm but it has been intermittent ever since and discontinued (due to a lack of orders) some years ago. The client base of the firm is, to a great extent, a sub-set of the client base of the renowned machine tools manufacturer for which the owner worked. Marketing is based on the personal contacts of the owner with that sub-set of clients. Besides marketing, all management aspects are controlled by the owner with the help of a daughter who helps him with the administrative tasks. No automation whatsoever, even of the administrative tasks, was introduced.

The attempts of the firm to manufacture machines, namely presses, were soon destined to fail. The presses it manufactured were small, light, low power presses with specific functions and were extremely simple and basic. For instance, around 1983-1985, it manufactured a hydraulic press to compress tobacco leaves while putting them in a sack. It consisted of a metallic structure one meter high with a pneumatic arm coupled to a sort of plate that compressed the material while descending. The sack had to be put in place manually and held in place while the pneumatic arm descended. It was clumsy, with no minimum precision, fragile, dangerous and involved a lot of labour force. This machine was manufactured by order of a large tobacco company that only bought a couple of such machines. It soon got rid of them selling them out to farmers. It manufactured a similar machine for a large chemical manufacturer (a state-owned firm) but the outcome was similar, i.e., it only sold a few machines. The fate of these last machines is unknown. In the meantime it was able to manufacture other simple machines. Overall, since its foundation until the present moment, which totals approximately 16-17 years if manufactured 30 simple presses and 12 other machines which says it all about the success of the firm as machine tool manufacturer. It seems that there was here an inconsistency between the clients that the firm looked for and the product quality/features the firm was able to provide. Apparently the owner looked for the large clients of the bankrupt renowned firm because these were the clients he knew and because he was expecting (and rightly so if all the conditions were met) that those firms would ask for large orders. But the facts seem to show that those firms were profoundly unsatisfied with the products manufactured by this firm. They were only temporarily fooled by the ex-foreman of the excellent machine tool manufacturer that went bankrupt. The products manufactured by the spillover firm were far behind from the products manufactured by the source firm. In spite of this, it seems that the owner did not look for another type of less demanding clients, but insisted on approaching large firms. Today it still looks for those firms as the port of salvation. The main production at this time is a large drill (only the drill not the machine) that it manufactures under the order of an important firm in the field of geology. It is a helicoidal heavy piece of iron with no special characteristics. It also recently built the structure of a washing machine for trucks and buses, again to a large transport firm, but again it manufactured only one unit. Given the production and management conditions, the knowledge base and the marketing approach, and the adverse environmental conditions that unspecified non-precision component manufacturers face (intense competition, increasing demands on the quality of the components, alternative materials for components) the future of this firm does not seem promising.

The innovative firm was established in 1956 as a manufacturer of small equipment and as a repair shop, an activity that it pursued until 1961, at which time it started the production of machine-tools, namely guillotine shears (to cut metal sheets) and later on, in 1964, the manufacture of press brakes (to bend metal sheets), the two main product lines of the firm. It also manufactures (more traditional) presses but its share in total sales is now much smaller. It specialised early on in its lifetime in the first two product lines, i.e., in the product lines related to sheet metal machine-tools. The founder was a mechanical engineer and his son, now in charge, is also a mechanical engineer.

Product development in this firm was and is a constant activity ever since its beginings. Mechanically driven machines were soon replaced by machines with pneumatic and hydraulic devices that enhanced their performance. For instance, the first machines did not go beyond a capacity to cut metal sheet 6.7 mm thick and 3 m long (in 1961). With the introduction of pneumatic devices that capacity improved to 10mm thick and 10 m long (1965). The next improvement was in 1968 with the introduction of servomechanisms that enhanced even more the performance of the machines (both guillotines and press brakes). The servomechanisms were obtained from a Swiss firm and they were used for quite a long time.

The firm soon became one of the main national producers of such metal sheet equipment (presses were relegated to a secondary position due to the relatively large numbers of national firms producing the same type of equipment). Facing limitations in their development and growth due to the size limitations of the national market it decided to enter the export market, which it did in 1968, exporting to Europe and to the Portuguese African territories. Later it started to export to the United States and then Asia. Presently it exports 80% of its total production of which 30% to 35% is destined to EU countries (including the Scandinavian countries belonging or not to the EU), 30% to

USA and Canada, 15% to Asian countries (the main destinations are Thailand, Singapore, Malaysia and Taiwan) and 5% to the rest of the world (including Australia and North-African countries).

The technological evolution of the firm's products has been increasingly subject to the requirements of its external customers as the share of total production aimed at external markets began to increase and then became the major part. The main competitors of the firm became the foreign firms competing for the same clients and not the internal firms competing for the national market. It began to participate regularly in the most important international fairs of the sector, an activity that is both a way of marketing its products and a way to know what the other producers are doing (and also as a source of ideas for new improvements). The two main product lines were subject to new improvements. The most important ones are the adoption and improvement of new techniques and devices to perform more accurately and reliably the main functions of the machines, namely, to cut (in the case of the guillotines) or bend (in the case of the press brakes) metal sheets. The differences in the main techniques/technologies for the guillotines are related to the type of synchronism of the movement of the parts that support and move the cutting blades and the position inside the machine of the main mechanisms and devices that control movement. Developments of the underlying principles and perfection of the techniques, devices and materials required by those systems enabled the firm to introduce in 1968 the so-called "variable angle cut" and in 1974 the "oscillating cut". With regards to the press brakes the technologies are related to the introduction of devices that assure bending homogeneity and increase the deflection precision, or in other words, that increase the quality of the bend which is determined by the accuracy and consistency of the bending angle throughout the length of the bend. Additionally and in parallel there is a constant preoccupation with material quality, robustness, ergonomic design and safety.

In 1979 the firm made another technological jump and started the manufacture of CNC machines, or to be more exact, it introduced computer numerical control in its two main product lines. Aside from that it continued to introduce constant incremental improvements in the machines affecting the performance and quality of the main function of the machine as well as affecting its possibilities of coupling with other productive devices/functions, its durability, its ease of operation and its safety. The machines were now able to cut metal sheets up to 25 mm thick and 10 m long (depending on the type of metal). In addition there were a number of other improvements. For instance, the construction was now heavily based on increasingly sophisticated welding techniques (so much so that the firm established another separated but affiliated firm exclusively dedicated to welding), the design of the superstructure was optimised by computer calculus and simulation, there was a number of auto-adjustable mechanisms (such as auto lubricated moving parts, self-regulated holding compression force, etc.), selected improvement of the material of the parts according to the function it was performing on the machine and the wear and tear to which it is subjected, devices that fine tune delicate movements of large moving parts, improvements in energy consumption, design of the machine to enhance its ease of operation and safety characteristics as well as the introduction of specific devices that enhances operator safety. The CNC devices permited a series of modes of operation as well as the programming of machine operations. They also permited the programming of interactions of the machine with other auxiliary external devices (such as for instance the automatic intervention of support tables for feeding sheets, the intervention of devices to automatically collect and store sheets after they are cut, connection to a remote computer, etc.).

Technologically the products made by the firm are at the second best level compared with world state-of-the-art. This technological level is partly a deliberate choice of the company. One of the factors behind that decision is the lack of world reputation or image of the whole country as a manufacturer of technologically advanced products. The state-of-the-art machines of this kind (performing the same function) are extremely sophisticated and engineered, very reliable and very expensive and they are manufactured by developed countries (Swiss, Germany, USA) with an established tradition of competence on the world market. Portugal does not have such a tradition (the world image of Portugal is of a producer of primary products such as wine or low-technology industrial products such as textiles). Therefore the firm believes that it would be extremely difficult to find international customers at that technological level if the firm would choose to enter such a level, except if the price was extremely competitive which is an impossibility for the firm. Within the medium-high technological platform on which the firm operates the competition is amongst a greater number of producers but the machines are evaluated by their virtues and the firm's products can stand out if they are able to compare positively with similar ones.

The product philosophy is based on what the firm calls the "evolutive concept", which is based on the construction of a common superstructure for all the machines and the differentiation of the machines by complementing that superstructure with differentiated devices or characteristics. So, within each product line, there is a basic machine model or skeleton to which can be added additional devices depending on the characteristics required by the customer. Some of those devices are standard, others may be easily-made modifications of standard products, and others still can be ordered and tailor-made. The machine can also be adapted and programmed to interact with other external devices. Again, the firm provides a choice of possibilities that goes from standard, close to standard and tailor-made external devices.

In this way the firm tries to conciliate and explore the cost advantages of mass production with the market advantages of batch production. However production problems are felt quite strongly in the firm. It is perhaps one of its main concerns now. Aside from the automation of administrative procedures they have also automated the management of stocks and orders by means of a relatively sophisticated software package. The firm has experimented and tried to introduce new approaches and techniques of production, such as JIT and CAD/CAM but it has proven difficult. CAM, CIM and JIT production were implemented but only partially, i.e., only on some production lines. The difficulties stem in part from lack of qualification and preparation of the workers that are apparently unable or slow to adapt to new production forms and conditions (namely they are unable to understand how the factory operates and the importance of their small actions to the smooth functioning of production). Problems are also derived from external constrains, in general those linked to difficulties in making the suppliers or subcontracted firms abide by strict delivery deadlines. In general this is linked to certain vices of production, such as the tendency to put all orders in the same sack and produce large series instead of small batches. For instance, if the firm issues an order to a sub-contractor consisting of three pieces type A for Monday plus three pieces type B for Friday, the tendency is for the sub-contracted firm to deliver all six pieces on Friday because it is less costly. JIT production presupposes quick set-up times, which is a condition not met by many sub-contractors who are not using modern adequate equipment nor management techniques. Another problem is the lack of a large enough national base of specialised sub-contracted firms, which forces the firm to make many parts and excessively complicates the management of production and its automation. Behind these difficulties are probably limitations in the firm's knowledge base relative to production management. The firm contracts out many activities and reserves for itself the work related to design, work related to shaping metals, machine parts, machine interfaces and assembly. Its trend is to become more and more an assembler of systems. The creation and separation of the above-mentioned firm dedicated to welding is a consequence of this logic. Every part of the machine that requires welded construction is contracted out to that firm. All the electrical, electronic and computer control components are also contracted out. Many machine parts are also contracted out and it is not more only because of the difficulties mentioned above. The firm tries to circumvent such difficulties by establishing close relationships with some sub-contracted firms, providing training, tools, production specifications and in general everything necessary so that the sub-contracted firm manufactures the part as well as they do.

At the management level, the firm tries also at least to follow the lead. It has a separate R&D department to which it attaches a great deal of importance. The R&D department is organised by market, i.e., by product lines. There is one section of the department that deals with guillotines and a certain type of presses and the another section that deals with press brakes and a second type of presses. Additionally there is a third section that deals with the integration of electric and electronic components. The main product line sections have each two mechanical engineers, aside from the designers, who are professionally educated at higher secondary level or medium level. The electronic section has an electric engineer and an electric technician with a short-cycle higher education course. There are concerns with teamwork and explicit actions to enhance work based on teams, which involve not only the R&D department but also the marketing and production department. An engineer leads each department, including the marketing department. An economist leads the finance department. The firm elaborates quite carefully an annual plan after a thorough evaluation of its strengths and weaknesses with demanding qualitative objectives, and also a five-year plan with more vague and qualitative considerations and goals. At the end of each year the annual targets are compared with what was actually achieved and future plans of actions are drawn accordingly and taking into consideration the lessons that it learned from the ending year.

The firm maintains a relatively large web of contacts, at least if compared with the majority of firms in this sample. Aside from its relationships with the sub-contracted firms described above, whereby the flux of knowledge goes essentially from the firm to the contracted firm, it has also participated in a project that involved another firm in the equipment goods sector and a university. It has submitted applications to participate in EU programmes but unsuccessfully until now because they have difficulties in finding a partner that is not also a competitor. Their main outside link is with the Engineering Faculty of the university in the city in which they are established. It is a regular and constant collaboration and established quite some time ago. The origins of such collaboration, asides from its geographical proximity, are linked to the fact that many of the engineers were educated and graduated at that institution and they have contacts with former teachers or colleagues. Many incremental improvements in the machines are a result of this collaboration. It takes advantage of more sophisticated machinery that the Faculty possesses, namely in the fields of computation (for calculus and simulations) and electronics (for specific applications development). It resorts frequently to the sector’s technological centre for instrument calibration, certification and quality tests. It collaborated once with a state research laboratory and with another engineering faculty in the capital city. Relative to technological matters it has resorted to international consultants but only occasionally to national consultants to whom if refers with criticism, saying that they are inexperienced and opportunistic.

This example almost speaks for itself because the factors embodied in each firm and the trajectories they followed are so contrasting. The average firm starts from a very weak knowledge base and relies excessively on the practical experience their members acquired in previous working positions. Marketing and the target customer are inadequate for the present conditions of the firm and there is no effort to upgrade its technological capacity (the owner blames its competitors and complains of unfair competition but it never refers to the quality of its products). The innovative firm, on the contrary, incorporates a range of factors, including management practices at administrative and production level which makes it quite innovative and successful. The selection criterion is clearly at the level of the innovative content of the products and at the level of the adequacy of the product to the requirements of the customer (which includes an important component of after-sales service).

11.10 MECVER and GUIFIL (Pair 9) – worlds apart II

The history of this pair of firms is somewhat similar to the history of the previous pair, particularly as regards the innovative firm. The average firm in this pair diverges from the average firm in the previous pair in the sense that it is much more determined in the decisions it takes, particularly in the decision to abandon a product line and in the ability it has to find alternatives. It also benefited from improvements in the qualifications of its personnel both at shop-floor and at design level, although it is relatively modest at this latest level. However this proves to be adequate and sufficient for its present product line. This dynamism and determination makes the difference between an almost inevitable "announced" death of the average firm in pair 8 and survival of the average firm in this pair.

The average firm was founded in 1982 by a couple of brothers. Both had secondary level professional training and working experience in the metallurgical sector. One of them worked as a welder and the other as a machine operator where they gained an important practical know-how that it would be the basis of the firm which started first as a small workshop manufacturing metallic welded structures. Later it started the production of small presses for the agricultural sector to compress specific organic products. The machines were very simple, similar to the ones manufactured by the average firm in pair 8. The firm soon split into two. The welder moved into other larger premises and abandoned the manufacture of presses for which he saw too much competition and not much future and dedicated the firm to the repair of agricultural vehicles and later vehicles related to civil construction. Aside from the maintenance of the motor the firm repaired the body of the vehicle, namely the hydraulic components of those machines (e.g., lifters) and manufactured replacement parts. In its quest for orders it managed to arrange one from a large manufacturer of electric products which would constitute an important part of the firm turnover (about 80-90%). The order consisted of the partial manufacture of metallic boxes for electrical transformation posts. The firm had to weld all the components. This was its only job. The large firm provided everything else. It provided all the drawings, all the materials and all the specifications and precise welding instructions and training. This service was beneficial to the firm in two ways. First it gave the firm a constant stream of work and security during almost six years and second it improved substantially its skills in welding by virtue of the regular annual training it received from the large firm.

The early 1990s' recession diminished the orders from the large firm but fortunately the firm by then found a smart way to combine its available skills and practical know-how. The social contacts of the owner and his quick perception of business opportunities are behind the product re-orientation of the firm. The firm decided to manufacture garbage containers, equipped with a hydraulic system to compress the garbage, to fit into garbage trucks. It also secured the maintenance of the trucks, including the motors. By defining this business it combined all its skills in one product line. Its welding skills were used in the manufacture of the container body, its skills in press manufacturing and repair were applied in the garbage compressing mechanism and its skills in repairing motors were also applied, enabling the firm to provide a complete and integrated garbage fleet manufacture and maintenance service to its customers. This decision was made around 1991. At the time there was a small number of firms operating in that business and there was an increasing concern by city councils with the garbage situation due to the ever increasing quantities of waste and also by the requirements imposed by law (of which the EU laws are an important component). The fact that the owner worked in the city council as an elected local representative explains partially the business insight he so cleverly grabbed. The firm quickly contacted a great number of city councils nation-wide and was able to sign contracts with many of them. This line of activity (manufacture of garbage container and respective equipment and maintenance of garbage fleet) represents now 80% of its activity. It continues manufacturing, or more precisely, welding (everything else including materials is provided by the other firm) the metallic boxes for the large firm and its welders continue to receive annual training. They also manufacture individual components under order.

At the same time the firm decided to upgrade a little bit its knowledge base and it admitted a highly educated (but not graduate) technician (a university drop-out from a course in mechanical engineering) who now carries out all the design part of the products. The conception of the product was based on visual observation and imitation of similar imported products. The firm manufactures almost everything in-house, inclusive the hydraulic components (except plastic or rubber parts such as rubber seals). The only operation it did not perform was bending the metal sheets but it acquired recently a machine to do that (a press brake). Except for this last automatic machine which is relatively sophisticated, all the other production equipment is non-automatic and mechanical. It does not have a painting cabin which leaves much to be desired in the quality of the painting.

Administrative functions are automated; cost control and time control were automated with a software package acquired a couple of years ago. It has used CAD for about a year now. Strategic management is based on the visionary capacity of the owner and on the day-to-day management of orders and production. There are no formal plans of action, either long term or short term. Contacts with the outside, in terms of technological transfer or co-operation with other firms is reduced to the know-how provided by the large firm under the conditions mentioned above. The admission of the highly educated technician will eventually enlarge its contacts.

The most recent and bold movement of the firm is the (possible) establishment of an agreement with an African country (an ex-Portuguese colony; it is interesting to note here that many internationalisation efforts of the firms in this sample began with Africa) to manufacture, repair and maintain the respective garbage fleet. It has already installed a workshop in that country with some machines and a small team of workers. They will assemble the containers and equipments manufactured in Portugal and sent by ship, and will provide for the maintenance of the fleet.

The innovative firm was founded in 1934 manufacturing moulds for the glass industry and as a repair workshop. With the progressive integration of workshops within the structure of the glass factories the firm had to re-orient its activity. In 1944 it started to manufacture equipment goods. It manufactured all kinds of machines. It started manufacturing presses and then guillotines but it also manufactured smoothing planners, lathes, milling machines, and a plethora of small machines. Every product was manufactured under order. When more manufacturers surged and competition increased the firm re-oriented again its product lines and, during the 1960s, it decided to specialise in a narrow range of products, which are guillotines and press brakes.

Concern with constant technological improvement was always present in this firm and it always relied essentially on its own development activities and a constant upgrading of its skills and knowledge base. The products were subject to basically the same trajectory described in the previous pair (Pair 8) concerning the innovative firm.

Initially the machines were mechanically driven, then begun to incorporate hydraulic systems and in the late 1970s and early 1980s CNC was introduced. Parallel developments in ergonomic characteristics, safety devices or design, operations facilitators and coupling with external equipment accompanied the main developments in the machines. The firm has also specialised since 1978 in a particular technological principle namely the so-called “vertical cut” in opposition to the so-called “oscillating cut”. The former is based on the positioning of the hydraulic cylinders that command the movement of the blades at the bottom of the machine and there is serial synchronisation of the cylinders. The latter is based on the positioning of the cylinders at the top of the machine and on mechanical synchronisation, and it suffers from the inconvenience of increased potential mechanical distortions of the structure and/or the tools. Its main recent developments are the introduction of CNC and the introduction of interfaces that allow easy coupling of robot systems to the machines. Presently the variability of optional devices and models is quite large. Its product and production philosophy is based on batch production of a few basic models, but it also manufactures special tailor-made models or machines under order. Its motto is flexibility. Investment was made in new production equipment and upgrading of the existing one and production management is in an advanced state of automation, incorporating advanced CAD, CAM and CIM systems (but not in all lines of production). The trend towards automation begun in the mid 1980s and major investments in integration were made in the early 1990s.

The firm experienced severe limitations to its growth during the 1960s (due to the small size of the domestic market) and it begun to export. Its first export markets were Spain, USA and UK. Fearing excessive dependence on a small number of export markets (and recalling its earlier dependence on the national market and the problems that it caused in the past) the firm engaged, in 1992, in a policy of diversification of markets. Nowadays it exports, on average, 80% of its production to about a dozen countries including the EUA (its main export market) the EU countries (including Scandinavian countries), Asian countries (Thailand, Japan and Taiwan) and some countries in Africa and South America. These are the main markets but it exports to other countries.

The firm has a separate R&D department to which it attributes a great deal of importance. Presently there are about six engineers working full time in development activities. It makes a quantitative 3-year plan concerning strategy and investment (for the export component only; there is no plan for national orders) and a five-year non-quantified plan with long-term objectives. There is also a large and comprehensive training programme that involves not only production workers but also managers at all levels and in all departments. Outside links include close co-operation with sub-contracted firms to which there is a team solely dedicated, and co-operation with the university, namely a Faculty of Engineering (but apparently the firm is not very satisfied with this co-operation mainly because of time delays). Management priorities are now in terms of project (R&D), management of sub-contracted activities, sales and after sale services.

An additional comment is due comparing the two innovative firms in the last two pairs because both the innovative firms in pairs 8 and 9 share a similar story. One started around late 1930s producing moulds for the glass industry. The other was founded in the mid 1950s, as a machine repair shop and manufacturing small machines. The former abandoned the manufacture of moulds when the glass industry incorporated their manufacture into their factories, and it then started to produce machine tools. The production was diversified (presses, shears, press brakes, lathes, etc.) but there was a non-coincidental relation with their former activity (making moulds with presses). Competition during the 1960s led them to specialise in two products. The other firm adopted a specialised strategy earlier in its lifetime and they have been consistently in the same product line since the 1960s. Both firms show a quite clear vision of their goals and their strategy. Both began to export during the late 1960s, because the internal market was not enough to provide a basis for expansion, initially to Africa and then to Europe. Now they export 80% of their production to Europe, the United States, Canada, Asia and for other countries as well. The diversification of markets was adopted to prevent an excessive reliance on one country alone (a problem that was felt earlier, before they began to export, and later during recession periods). They both produce, on a serial basis, a core machine body to which they then add electronic controls, CNC controls or other peripherals according to the requisites of the customers. They also produce tailor made products and offer a series of options that can be added to the basic machine, including coupling systems to robot flexible manufacturing systems.

The selection criteria for these firms have been based on the interplay between technology, performance, quality and price. The technology of the products is average/above average, not state of the art, but their quality, efficiency and reliability are excellent in the range at which they operate, and the price is competitive compared with other producers of similar equipment in the countries to which they export. This mix of qualities has proven to be quite successful. When describing their respective histories in a preceding section we compared them with an “average” pair but, having in mind the trajectory they followed, it becomes clear that their main competitors in the national market are themselves, and that their main competitors (in absolute terms) are firms from the markets to which they export or firms that have an intense export activity like themselves. It is therefore appropriate and pertinent to compare the two firms. What distinguishes them is not the technological level or complexity of the products, which are in almost all respects identical or comparable, but the way that the same technology is incorporated into the design of the machine and in that respect one of the firms has a superior degree of flexibility compared to the other firm. The firm in pair 9 has the capacity to produce a larger variety of machines than the other has, at no extra cost. However, this increased batch production capacity seems to be obtained by sacrificing the scale of production at which the firm in pair 8 compares most favourably with the other. Both firms are likely and able to grow. It will not be a surprise if they do it by fusing their activities.

11.11 EFACEC (Case 10) – a multinational tradition

The history of this firm gives a perspective on how a Portuguese firm successfully built up its own capacity through formal transfer of knowledge and technology. The firm was founded in 1911, as the result of a partnership between a Portuguese family and a Belgian family to manufacture electric motors. It was a partnership based on the complementary of technological knowledge that each partner brought with them. Before the partnership the Portuguese family was active in metallurgy work and it had recently begun to experiment and to diversify into the electrical components business. The Belgians brought more advanced electric knowledge to the joint venture. For the first ten years, the main product remained electric motors, but after that the firm begun to diversify into the fields of energy transformation and generation. In 1921 a new company was created, involving the same two shareholders and it reflects on the one hand, its expansion and diversification approach, and on the other hand its definite encroachment on electromechanical machines. Aside from electric motors, the company was now increasingly active in the manufacture of transformers and other electric apparatus as well as components and accessories of several sorts. Later, an affiliated firm, manufacturing electric boards, was created. By this time the diversity of customers was high. They provided for a wide range of demands from the public, private and industrial sector. The public sector became increasingly important, due to the continuous and accelerating building of the communications and energy distribution infrastructure systems. However, only after the Second World War would demand from the public sector affect in an important way the growth of the firm. In 1948, the firm was larger than average for national standards. Its success attracted the attention of large firms, and two new entrants made their debut in the firm's capital structure. One of the firms was a Portuguese corporation linked to the chemical sector and the other was another Belgian firm in the electrical/electronic sector. The new capital provided the firm with the financial capability to enter into more ambitious and demanding product lines, namely large equipment for electric generation and distribution. Besides the previous accumulated knowledge, the Belgian firm provided the know-how, and the firm manufactured the produce under licence. The first 200 KVA, 1.5 tonne transformers were built in 1949 and the first medium-tension circuit breakers followed suit. It is also by this time that the firm started to produce on an industrial basis, adopting a clear division of labour and heavy mechanisation of the factory. This organisational mode of production was applied to the mass production of electric motors. Larger and more potent transformers followed soon afterwards, as well as the manufacture of high-tension circuit breakers.

Eventually the Belgian firm took control of the company in the mid 1950s, buying out the part of the capital in the hands of the chemical corporation, acquiring a 70% majority stake in the company. It would control the company for the next thirty years.

The period in the firm's life that started with the Belgian take-over coincided with a moment of great development of the Portuguese economy. High public investments in the national electric infrastructure most benefited the firm during this time, sustaining a steady and prolonged period of growth, greatly helped by the fact that it enjoyed an almost complete monopoly over the Portuguese market, due to the absence of internal competition, for there was not any comparable firm in the same product lines, or indeed competition from abroad, for its position and market was secured by considerable tariff and political barriers.

For the next two decades or so, it basically continued with the same two main product lines: electrical motors and power transformers. The products were subject to continuous developments and improvements, but these improvements were not based or derived from its own R&D activities but rather from the R&D activities pursued by the mother company abroad. The new products were developed at the mother company's headquarters and the firm made only slight improvements or adaptations to meet specific local circumstances.

Even after the great expansion period that the Portuguese economy enjoyed during the 1950s, 1960s and early 1970s, the firm continued to grow appreciably. In the early 1980s it created an electronic department, aimed at the implementation and integration of electronic circuitry and control devices in their products. It also started the production of automatic systems for power plants. By the mid 1980s it started to automate its factories producing electric motors. By the end of the 1980s the (two) factories that produced motors were completely automated, using the latest technology available.

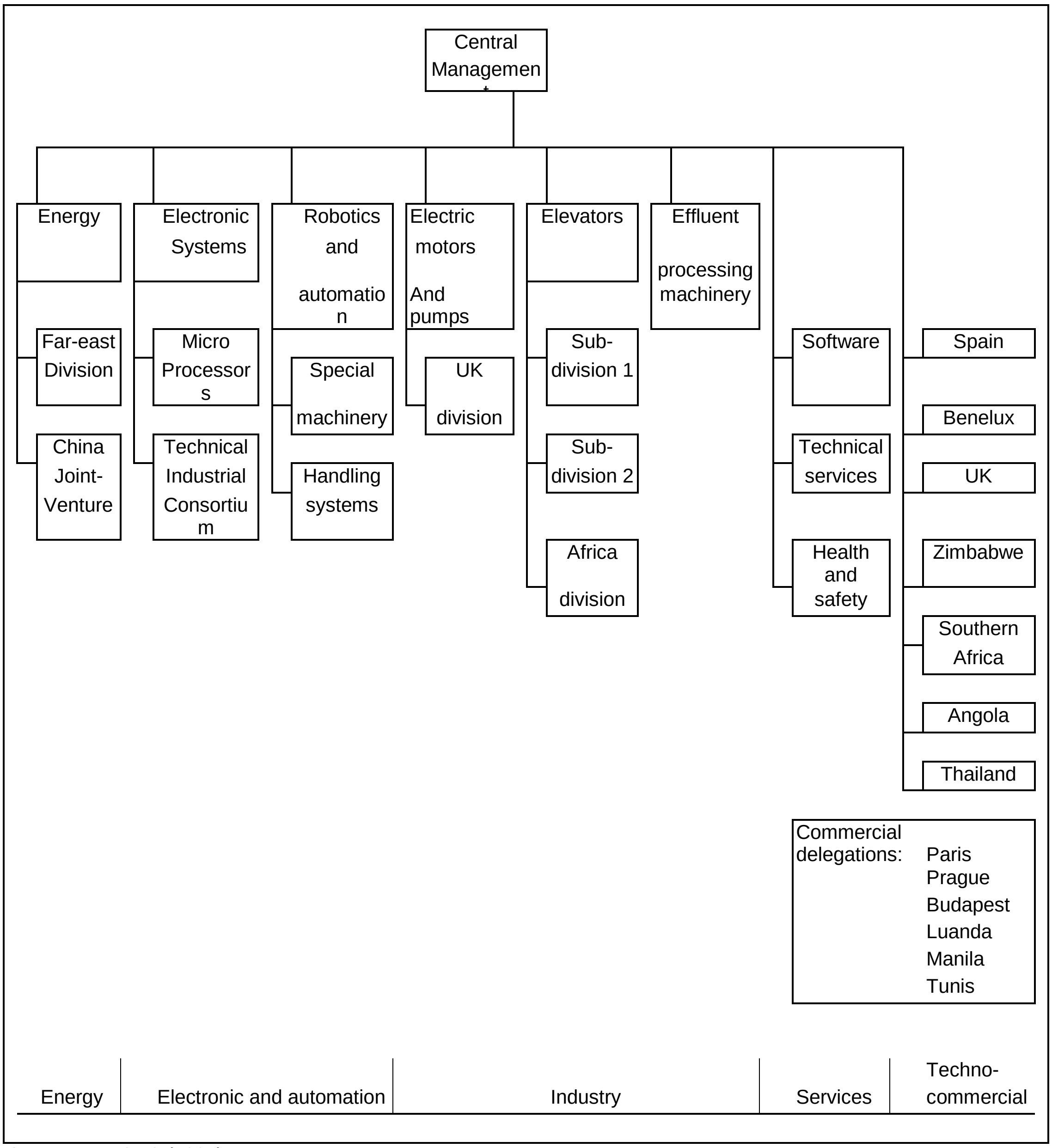
The late 1980s were a turning point for the firm. The Belgian shareholders that controlled the firm for nearly thirty years abandoned completely their position in the firm. The firm was not acquired by another large conglomerate. Its equity was widely dispersed, following a public offer, and no single entity acquired a majority share in the firm. The largest single position (around 12%) was acquired by a Portuguese financial group that had stakes in several industries. The management tried recently to trace the possession of the capital of the firm and it was able to identify only 50% of the total, which was itself widely dispersed among several shareholders.

The firm was now, for real purposes, in the hands of the technostructure, with no single controlling stake in its administration board. It was not a management buy-out but the management effectively took power. This unusual situation, at least by Portuguese standards, and certainly a drastic change for the firm, apparently did not prevent it from acting efficiently and to prioritise its activities. The management quickly devised its plans and a big change in strategy ensued.

The change was characterised by three fundamental facts: 1) investment and reliance on in-house technological development, as opposed to the dependence on licence agreements, 2) re-organisation of the firm based on product market divisions, and 3) the necessity to export to recoup and sustain the costs of in-house development of technology.

All these strategic factors represent a radical departure from the previous orientation of the firm and it has shaken considerably its structural features. The firm has, in a relatively short period, evolved from the dependent subsidiary of a foreign corporation into a fully-fledged and expanding company with multinational characteristics. The firm is now organised as a holding group, comprising several product divisions. The present structure is represented by the organogram in Table 52.

Table 52. EFACEC organogram.



Source: EFACEC (1995).

Each division is responsible for its own management, production and R&D activities, and is treated as a different profit centre. The board of directors that includes the director of each division carries out the overall co-ordination. The board of directors nominates the administration board (except the member from the financial group that possesses the largest single share). The firm employs modern management techniques, which include management by objectives, project oriented programmes, R&D as a cost of production, emphasis on training, and recruitment of highly qualified personnel. Their newest objective is to attract post-graduates at the doctorate level. The firm has multiple agreements, co-operative arrangements and projects with universities, research laboratories and technological centres. It is a shareholder of the recently created science parks and innovation agency. It has also agreements with other firms and is involved in a series of development projects with other multinationals. It constituted a joint venture with Chinese partners to manufacture transformers and other energy equipment in China.

R&D activities are now considered essential and the firm compares its own R&D intensity with the R&D intensity figures of the main multinational firms in the same sector (and it is still considerably lower, by a factor of three, which is a source of great concern for the firm). Availability of finance is not seen as an impediment to R&D activities, and arguments based on financial resources are not accepted as a reason to not pursue a certain project. Presently, two-thirds of their investment is derived from external funding.

It is now involved in an aggressive export policy. It started with Africa, the Mahgreb countries and the Arab countries, and is now exporting to a wide variety of destinations, including Europe, Asia, North and South America. The pattern of export is not even. The European and North-American markets absorb mostly its electric and electronic products, while the other markets absorb the heavy equipment for generation and distribution of electrical energy. The firm is trying actively to penetrate the European market in this latter product line, a goal that has proven difficult to achieve, due to subtle protection barriers that exist in the market for heavy electric machinery in those countries (according to an explanation given by the firm). On average, and considering all products, the firm exports 30% of its production.

Domestically, the main clients are still in the areas of electric utilities, the railroads and communications. In terms of products, although the energy sector maintains its importance in the sales portfolio of the firm, the electronic products have acquired an increased importance and are now the fastest growing product line.

Although the firm passed through, at least, three different periods characterised by different structures of ownership, it seems that a steady and continuous growth path, underpinned by a rather early-defined strategy in terms of product specialisation marks its history. The initial stages, characterised by a broader product range, were soon followed by a concentration of efforts on the two main lines of production (electric motors and heavy electric equipment). Government procurement and the fast structural change and growth rate the economy experienced during that period, particularly after the 1940s, are not isolated factors from the specific strategy the firm then followed, nor is the fact that the firm enjoyed a substantial degree of protection from outside or inside competition divorced from its continual growth.

On the other hand, the diversification strategy followed just after the departure of the foreign investors shows how constrained it was by its former strategy. After all, the scope of applicability of the knowledge involved in the two main product lines was so broad, and its extension to other product lines could benefit so much from the accumulated expertise and the scientific and technological proximity, that it seems odd that the diversification into other products was not as extended as it was. There are, at least, two explanations for that. One is that the strategy and the competencies of the Belgian firm were themselves rather focused in terms of product specialisation, and that it transposed its own strategy to its subsidiary in Portugal. Another is that the subsidiary was only allowed to manufacture a limited number of products and thus its activity was constrained by the broader perspectives and the broader strategic concerns of its parent firm. In this particular case, the latter explanation seems to apply. The Belgian parent firm was involved in a much broader range of products than its subsidiary, and the market restrictions that the subsidiary faced seem to substantiate this view.

Even though formal R&D activities hardly took place in the firm, and the production engineers and the technicians were the most important functional sites of whatever development took place, this did not deter the firm from pursuing a completely different strategy after the Belgians left. In principle, the option existed to continue to operate in a similar fashion, based on licence agreements and imports of technological knowledge, but, apparently, the firm was sufficiently confident in its own capabilities to believe that it could develop its own technological knowledge and its own products. This is not surprising, at first sight. Its long history of manufacture of specialised product lines contributed enormously to the gradual accumulation of knowledge and expertise by the indigenous engineers and technicians. The very nature of the products explains how the subsidiary appropriated that knowledge. On the one hand, we have electrical motors, a relatively simple and mature product, whose principles are easily mastered. The concern related to this product is not so much with development but rather with production to make it cheaper and to take advantages of economies of scale. On the other hand, the heavy electrical production and distribution equipment was built not on a serial basis but on a unit basis, and that must have provided the production engineers with the opportunity to master its relatively complex principles and manufacturing techniques. Although the product was not designed by them, its manufacture and assembling were, and to do that, it was absolutely necessary that they had a detailed understanding and knowledge of the intricacies and complexities of the systems, because, by its very nature and by its demand characteristics and associated cost-benefit considerations, the product was not liable to be decomposed into simpler systems or components and manufactured by automated machinery. Such a situation would have put more emphasis on production management and on the function of the production engineers as supervisors of a manufacturing procedure, depriving the firm's engineers from the detailed knowledge that a manufacturing procedure based on the assembly of a single product gave them.

However, the competence of the firm to embrace with its hands its own destiny also involved an element of risk that should not be undervalued. First, although the capabilities were there, they remained, in certain domains, below the level of their competitors, and second, as any good manager knows, one does not necessarily (or even remotely) stay in the same place by doing the same things. The firm had to make the appropriate decisions to support, consolidate and make its option work. Albeit the past provided a strong technological baggage and experience, its inherited strategic condition or its structural organisational features were not necessarily the best guiding post to follow. In this respect, the knowledge, expertise and vision embodied in the highly educated staff played an important role on the re-orientation of the firm. The high number of graduates employed by the company was also helpful to sustain and facilitate the transition. The university background and the informed networks on which these people were included have certainly contributed to ease and make it more expeditious for the firm to tackle the uncertainties in its future and to implement its decisions. The presence of the financial group interests also added and gave strength to the managerial capabilities of the firm.

It is not possible to separate the selection mechanisms that affected the firm during the period when it was a subsidiary of a corporation from the mechanisms that affected that same corporation. Whatever they were, its technological competence notwithstanding, the survival and growth of its subsidiary are certainly linked to the lack of serious competitive threats. In a certain sense, the firm was not subject to any kind of selection, since there were no other available options. One can only speculate on the means by which the Belgian corporation was able to enter the Portuguese market and to bypass its international competitors.

The current phase of the firm is characterised by a much more competitive environment, whereby subsidiaries of other multinationals have entered the same product markets (some multinationals were in Portugal long ago, but the dictates of pre-1974 Portuguese industrial policy prevented them from competing in the same products) and competitive tenders for the same products, in government contracts, are now present. At the moment, the firm is still enjoying a certain degree of protection provided by its traditional clients, a situation that arises because the capital stock of those clients was supplied by the firm, and are thus dependent on the tacit and firm-specific technological knowledge embodied in those products. That dependence is particularly strong on the energy sector and the railroad system, whereby compatibility problems may prove difficult to supplant, or the integration of electronic and computerised systems of control may be particularly difficult for outsiders to accomplish due to the technological specificity of the systems. However, these advantages are not guaranteed and may be overcome. On the other hand, political factors also play a part in the preference given to the firm by the traditional state controlled clients, as governments tend to and are under pressure to favour national firms.

The combined R&D and export efforts of the firm are an important factor behind its present relatively successful situation. Its penetration in the international markets mentioned above, and its policy of diversification conferred upon the firm latitude that it did not have before, making it less dependent on a single product line or on a single market than it had been. It is still rather dependent on quite traditional product lines, in spite of its efforts, which may explain its unsuccessful efforts to enter into more demanding markets, like the European one, as it concerns its heavy electric equipment (if we are not to believe its claims that the reasons for its failures are of another nature). Insufficient development of complementary assets in those markets, such as technical services, consultants and software, is probably an added factor to account for, as the systems they commercialise are heavily dependent on such assets. However, considering that the firm has only recently begun its new life, it is perhaps too soon to precipitate conclusions. The firm is in the process of catching up, both in pure technological terms and in production terms. Its portfolio of co-operation agreements is a good sign of that process. One must wait and see if it bears fruits and how quick they will come.

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The following table is an attempt to organise all the qualitative information that was provided extensively in the preceding sections of this chapter. The table will help to identify more clearly and rapidly the key characteristics of the case-studies.

Table 53. Key characteristics of the case-studies.

Name	Pair	Group	Production automation	Design automation	Office automation	Intra-mural process innovation	Higher Education	Export	National Customers	R&D department	Formal planning	Systemic approach to development
Arvorense	1	Average							R			
Herculano		Innovative	4	4	4	4	4	4	N	4	4	
Vima	2	Average			4	4	4	4	N			
Mano		Innovative		4	4		4	4	L	4	4	
Avense	3	Average							R			
Industrial		Innovative				4		4	L			
Frama	4	Average		4	4		4	4	R			
Pinheiro		Innovative	4	4	4	4	4	4	N	4	4	4
Mecano-Textil	5	Average	4		4		4		N	4		
ACL		Innovative	4	4	4	4	4	4	L	4	4	

Table 53 (cont.). Key characteristics of the case-studies.

Name	Pair	Group	Production automation	Design automation	Office automation	Intra-mural process innovation	Higher Education	Export	National Customers	R&D department	Formal planning	Systemic approach to development
Maquisis	6	Average			4		4		N	4	4	
Seri		Innovative		4	4		4	4	L	4		4
Sersan	7	Average			4			4	R			
Prensarte		Innovative		4	4	4	4	4	L			
Diarroca	8	Average							R			
Adira		Innovative	4	4	4	4	4	4	N	4	4	
Mecver	9	Average		4	4		4		N			
Guifil		Innovative	4	4	4	4	4	4	N	4	4	4
Efacec	Case 10	Innovative	4	4	4	4	4	4	L	4	4	4

Legend: R – Regional customers; N – all types of national customers; L – large innovative firms

CHAPTER 12. GENERALISING THE RESULTS AND THE ANALYSIS: A FORMAL MODEL FOR UNDERSTANDING THE OBSERVED VARIATION AT FIRM LEVEL

12.1 Introduction

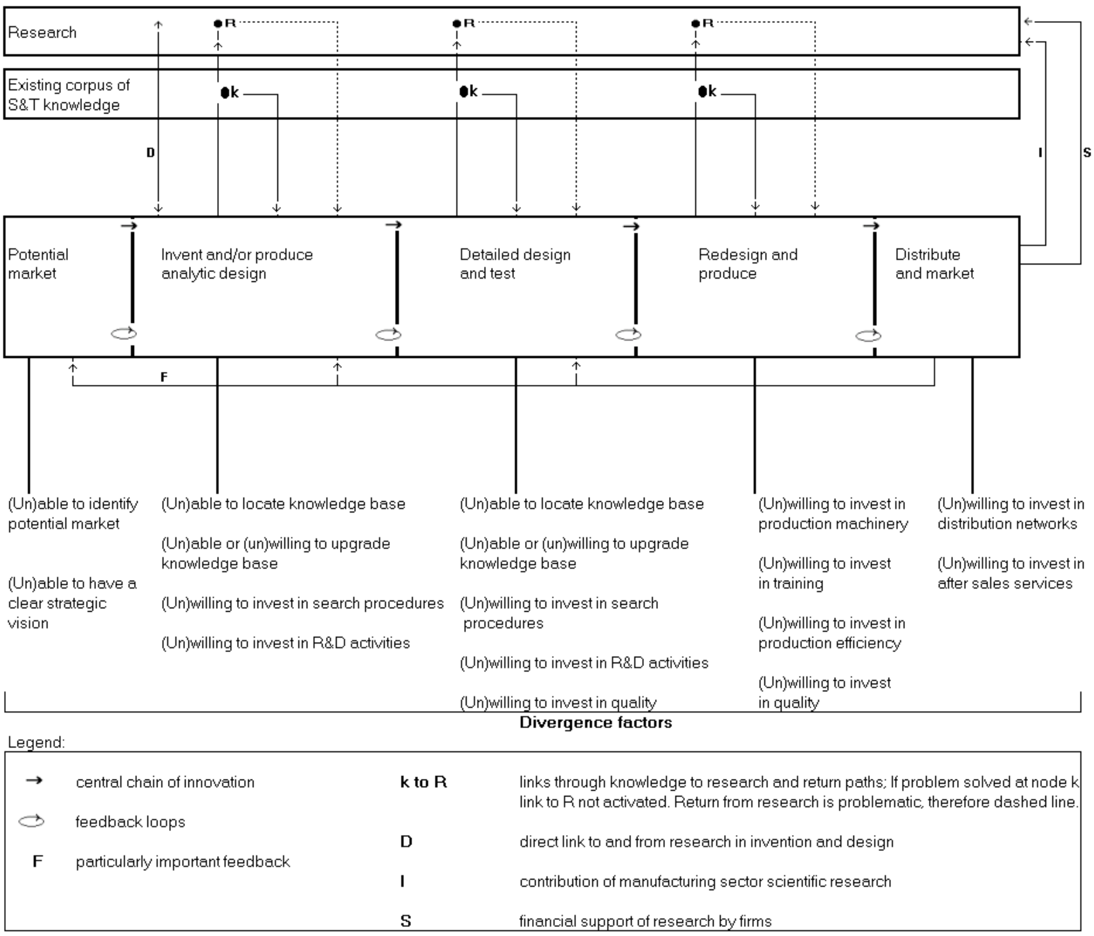
The last chapters described and analysed extensively the empirical findings regarding the individual firms that were the subject of this study. Chapter 10 identified, explained and analysed the quantifiable variables that showed up as important differential factors of the innovative behaviour of the firms. Chapter 10 described extensively and systematically the historical trajectory of each firm, emphasising for each firm (or pair of firms) factors considered particularly important for explaining the performance of the firm. In this chapter we intend to propose a generalisation, so that the previous exercise will not be eventually over-tuned with a descriptive tone. For that end we will propose an extension of a conceptual model that will help to explain the differences between firms, which are our main concern in this part of the thesis.

12.2 A dynamic divergence model

The considerations given so far suggest that as firms proceed along their path they encounter specific moments whereby a decision has to be made that will affect the future of the firm and it has to be made based on the existing strengths and limitations of the firm. The outcome of that decision process can either reinforce and improve the perceived strengths of the firm or it can set it even further apart from leading firms in comparable sectors of activity. Those moments were referred to as divergence points and some examples were given of certain decisions and the possible consequences on the global performance of the firm. By way of generalising it is useful to relate these crucial points to the process of innovation, and for that purpose we use the Kline and Rosenberg's (1986) chain-linked model of the innovation process.

The model includes a series of stages that define the innovation process at the level of the firm. At each stage we propose a series of factors that may push the firm on to a divergent path of low innovative performance, or conversely, towards greater innovative performance (Figure 13). At each stage there are factors that may be more important than others. They are not sequential, in the sense that a previous decision leading to a low performance path does not necessarily mean a subsequent decision favouring another low performance path. Since there are several possible combinations of factors, there are also several possible divergent paths and consequently several performance positions possible for a specific firm within a given population of firms at any time.

Figure 13. Innovation stages and divergence processes.



Source: adapted from Kline and Rosenberg, 1986.

This process of divergence, dependent on the behavioural attitudes of the firms, their choices and actions, can be represented by resorting to a biological analogy.

Table 54. Combinations of factors and deduced configurations.

	Factor combination	**Deduced configuration**
Firm 1	All factors present.	*excellent products *market leaders or main players at domestic level *very active in external markets *tendency to grow
Firm 2	No factors present or low grade factors (only internal training, short-term strategy).	*obsolete products *serving only declining firms at local level *likely to disappear in a short time
Firm 3	Automated equipment; Improvements in machinery; visionary strategy; information network reasonable;	*reasonable good products with no demanding technological concepts involved *likely to be component supplier in precision engineered products *serving essentially large firms but also a host of varied firms *potential to be in external markets as a component supplier *stabilised growth but eventual decline (if no other factors added)
Firm 4	High educational level; external training; low R&D intensity; Automated equipment; improvements in machinery; Good information network.	*good products with some level of demanding technology *manufacturer of sub-systems *serving large firms *possible sub-contracted firm of leading external firms supplying sub-systems *potential to growth but at a slow rate

Consider each definition of a particular variable in Table 48 as a gene and consider that the firm acts in a Lamarckian space, i.e., it can acquire features that make it better fitted to the environment on which it is immersed. Then there are several possible combinations of that genes and each combination will define a certain type of firm, or in other words and using the biological analogy, a phenotype. In the same way that a combination of human genes determines the global characteristics of a human being, so does the combination of variables define a firm innovative performance. Each gene or factor has its own function to fulfil and the factor related to management has the special and important task of co-ordinating all the others. We may liken it to the DNA, the fundamental source of information and guidance for the entire firm.

The model is based on the premise that the more new genes replace the old ones, the more likely that firm performance will be enhanced. The probabilities of innovative success are dependent on the managerial resources of the firm. Independently of these, the reasons why probabilities of better performance increase with new genes are based on the following assumptions: 1) the more factors are added, the higher is the probability that cumulative effects will lead to increased performance, and 2) the more factors are added the higher is the probability of increasing the absorptive capacity of the firm and consequently increase the probabilities of adoption of new factors.

Table 54 depicts several possible factor combinations and the deduced performance characteristics of the firm. For instance, firm 1 and 2 represent the two extremes. Firm 2 is characterised by a combination of low-quality factors or the absence of many of them, determining a technologically laggard firm, operating only on local markets and on the verge of extinction. Firm 1 represents the "ideal firm” that has acquired all the high-quality factors. Its innovative performance is high and it operates in international markets. In between, there are a number of possible factor combinations from which the global innovative characteristics of the firm, the products that it manufactures and the markets on which it operates can eventually be deduced.

12.3 Exploring the extended chain-linked model of innovation and testing its usefulness

The model proposed by Kline and Rosenberg and the extension previously suggested is based on a systems approach. The process of innovation is the main system and the main preoccupation is with its efficiency. The system is decomposed into subsystems, which are the research sub-system, the existing corpus of knowledge sub-system and the firm sub-system. The firm sub-system, in turn, is decomposed into lower level sub-systems, comprising the subjective perception of a potential market, the invention or analytic design production stage, the detailed design and test component, the redesign and produce element and finally the distribution and market part. The functioning and efficiency of the main system are dependent not only upon the individual functioning and efficiency of the sub-systems, but are also critically dependent on how and how well they are connected with each other. The model sets out to identify what are those connections and the links that are perceived to be the most important in determining the efficiency and coherence of the system.

The possibility to detect the cause-effect relationships between the sub-systems, and to identify in what manner those cause-effect relationships affect the efficiency of the main system was enhanced by the extension made to the model. We have made it by juxtaposing the so-called divergence factors upon the principal model. Specifically, we have tried to identify disruptions to the operation of the sub-systems and the way that impinges on the other sub-systems, and ultimately on the main system. In doing so we can extend the analysis and consider the internal characteristics of the firm, and if we can consider the internal characteristics of the firm in the context of the whole model then it is possible to combine the analysis of the external environment of the firm with the analysis of the internal characteristics of the firm, which was, we shall recall, one of the main objectives of this study. However, in what follows, will give emphasis to the internal characteristics of the firms, exemplifying the applicability of our concept of divergence factors to the explanation of the differences between the firms in the sample.

For instance, we suggested two kinds of disruption that can occur at the "potential market" level, which is the inability to identify a potential market and the inability to define a clear route of action, which are in a way closely connected to each other (the inability to identify a potential market may prevent a clear definition of the course of action, although the reverse may not be true). The “average” firm in pair 3 illustrates this situation. In spite of its efforts, the firm is incapable of defining its line of business and its product line, after the previous product line became obsolete. The implications for the efficiency of the sub-system "invention and produce analytical design" may include the persistence to maintain existent guidelines on design practice, the lack of aptitude to create a climate favourable to creative thinking or to contribute to undermine such a climate, and the incapability to focus search procedures and to create efficient links with the sub-systems "existing corpus of knowledge" and "research" and to make those efforts coherent, consistent and efficient. The implications on the sub-system "detailed design and test" are similar and are bound to be enhanced, if the disruptive course caused in the first sub-system is allowed to continue. Test procedures would continue without a clear orientation, diverting resources, efforts and attention and jeopardising efficiency. At the production stage, the signals from the upstream sub-systems would disorientate operations plans and the balance between acquisitions of raw material, inventory and stock. It would provide no orientations on how to proceed in decisions concerned with the modernisation of the production machinery or on what machines are needed, eventually resulting in unconnected and ill advised investments that would lead to over capacity or unneeded purchasing of equipment. Dispersed, unconnected and inefficient links, if any at all, with the "research" and "existing corpus of knowledge" would also be a most likely outcome. The same malaise would affect the feedback links. Distribution channels would be hard to choose, or subject to constant revising, and the distributors themselves would grow even more unhappy with the irregularity of the arrangements. As a consequence, the efficiency of the main system would be severely compromised, and the prediction that the firm will be characterised by a low level of innovative performance is not surprising. This is in fact the situation faced by the average firm in pair 3.

However, disruptions can occur at other parts of the system, located at middle-stream sub-systems and the consequences will be different. For instance, failure to acquire design skills, or theoretical guidelines to underpin invention, i.e., deficiencies in the linkage with the sub-system "existing corpus of knowledge", would result in fairly unimpressive designs, which in turn would have no demanding requirements on production machinery. The innovative firm in pair 3 is an example of such a situation. It, however, would presumably have no negative impacts on production operations and on overall production management, as long as the complexity of operations is not high, and that would be presumably the case if the product design is simple, which we are assuming it is, and as long as basic management techniques are present (i.e., a certain efficient amount of links with external sources of knowledge is maintained). A clear overall perspective of its goal maintains the efficiency of the system, and even if the goal (innovative performance) in this case is not ambitious, or in other words, the function for which the system was designed is not ambitious, that does not necessarily compromise its efficiency.

Although the “average” firm in pair 1 has defined rather well its line of business (agricultural machines) it failed to increase its knowledge base, jeopardising the efficency of the "invention and produce analytical design" sub-system. Market demand and new technological opportunities required that the firm made improvements in design of the machines which in turn required that the firm updated its knowledge and technological base. The implications were that the firm should have increased its links with the “existing body of knowledge” and internalise that knowledge if possible. One of the obvious ways to do that was by providing a higher education level to its personnel. However the firm failed to establish that link in a satisfactory manner. The knowledge base of the firm became increasingly distant from the available public knowledge and the firm’s products became increasingly inferior relative to more innovative competitors. Deficiencies at the production stage were felt in terms of the price of the product relative to other producers that manufacture larger series. The “innovative” firm, on the contrary, regularly updated its links with the “existing corpus of knowledge” in at least two ways. First by steadily increasing its own knowledge base (increasing the level of education and training of the personnel), and second by establishing regular links with other institutions. The link with the “research” block was also activated, which was made possible, on one hand, by the enhanced knowledge capacity of the firm and the possibility it created to engage in other type of contacts, and also by its own scanning activities and its own strategic investment in R&D activities. The need to create links with the “research” system became apparent when the firm tried to introduce optical devices in its mechanical devices.

The “innovative” firms in pairs 8 and 9 illustrate the situation whereby almost if not all of the factors were carefully and wisely introduced. Links with the “existing corpus of knowledge” or “research” sub-systems were actively although selectively pursued at the necessary points in time. Both firms defined at a quite early stage their lines of business and specialised rather early in their lifetime, after a short period of activity undefined in terms of product family. The decision to start export activities was correctly followed by an enormous importance ascribed to development activities, on the one hand, and to production management, on the other hand. The necessary links with the “existing corpus of knowledge” and the “research” system were established through several channels including training, education, formal and informal contacts with universities, research institutions and other firms. The technological level of the product (medium-high, not state-of-the-art), and the difficulties related to management techniques reflect eventually the limitations of the “research” system at national level and the inability of such a system to provide the necessary know-how to deal with state-of-the-art products (such as for example laser-based machine tools), or organisational settings, and to do so in a timely and cost effective manner. This argument is related to the limitations of the “research” sub-system (described in chapter 7) on the firm sub-system and it is also applicable to other “innovative” firms (namely in pairs 3 and case 10).

The “innovative” firm in pair 4 illustrates problems occurring in the production stage. Similarly to the firms in pairs 8 and 9 in the above example the firm defined rather early in its lifetime its potential market, was able to identify and increase the necessary knowledge base through links with the “existing corpus of knowledge” and the ”research” sub-systems using several communication channels, which included contacts with universities, research institutes, technical services, formal licence agreements and co-operation with other firms, and had in place the necessary distribution and marketing infrastructures to satisfy its internal and external clients. The disruption that occurred in this firm, and which compromised for a while its health, was at the level of production philosophy and production management, itself perhaps due to deficiencies in the connection between the “marketing and distribution” sub-system and strategic perspective in the “identify potential market” sub-system. The firm decided to engage in undifferentiated serial production of wood-working machine tools and to invest heavily in serial production equipment and centralised control and management of production. However, the emerging manufacturing paradigm based on batch production and flexible-manufacturing systems severely compromised the innovation process of the firm, namely in the way existing guidelines on design practice were misguided relative to market demands. The firm was eventually able to react to the market signals and to adjust its development and design activities emphasising product differentiation and batch production. However it faced difficulties in the transition period.

The “innovative” firm in pair 2 is an example that shows that it may not be enough to have the necessary links with the “existing corpus of knowledge” and the “research” sub-systems, which the firm had. In the case of this firm the deficiency was, on the one hand, at the level of strategic perspective and on the other hand at the level of distribution and marketing. The failure in terms of strategy was the inability to estimate clearly the size of the potential market. Estimates were too much optimistic and the installed production capacity was oversized in relation to market demand. There was also not enough investment in export markets differentiation and in commercial infrastructures in export markets, issues that should have been addressed having in mind the production estimates that were made.

To conclude, a systems perspective of the innovation process permits us to identify its component blocks and the important linkages that connect them. The proposed extended model, by observing the performance of individual sub-systems (at firm level) and the disruptions that occur at this level, and by identifying the deficiencies that occur at each stage in terms of interactions with higher levels (existing knowledge and research), makes it possible to deduce the consequences on the performance of other sub-systems and its relations with one another, and by combining the cause-effects relationships flowing across each component allows to deduce and draw the implications on the overall system (the innovative performance of the firm).

CHAPTER 13. EXPLAINING FIRM LEVEL VARIATION: A CONCLUDING SYNOPSIS

This part of the study started with a brief review of the literature concerned with the determinants of innovation at the level of the firm, outlying the evolving theoretical views that have underpinned our comprehension of the subject. Contributions to the understanding of the phenomena have came from several disciplines, notably from the economic, organisation and management literature. More recently the subject received attention from scholars in the field of industrial innovation.

We have identified in our empirical study of the Portuguese capital goods sector a number of variables that were significantly associated with the innovative performance of the firm. Some of those factors are quite similar with those identified by other studies (such as variables linked to management techniques and the impact of demand conditions) and they have been used to draw conclusions about the influences of external demand factors, as well as the influence of internal behavioural factors on the innovative performance of firms. Other variables were more specific to this study, such as the the impact of external sources of knowledge or the approach to product conception.

After having identified and compared those variables, we took a closer look at the particular trajectories of some firms and pinpointed the importance of some factors on the development of that process and on the way they have influenced the evolution of the firm. We explored some of the relations between the characteristics and the performance of the firms and the environmental selection criteria it faces and how they have differentially impinged on the firm's survival prospects.

Based on that analysis it was then suggested that differences in innovative performance could be explained in terms of the particular competencies that the entities acquired along their way and how they incorporated them within the existing structure of the firm. Failure to acquire specific competencies at specific points or insufficient reinforcement of existing capacities could jeopardise subsequent performance characteristics of the firm or limit the firm to a narrower horizon in terms of innovative output, due to the interactions between the several factors. We suggested, based on an organic, evolutionary perspective, that the presence or absence of specific factors would be reflected in different ways on the firm as a whole, depending on which factors were present and on the way they were combined together.

PART IV. EPILOGUE

CHAPTER 14. INTERPRETING SYSTEM AND FIRM LEVEL LINKS

14.1 Notes on the approach for connecting the system and firm level of analysis

When we started this study it was stated that its objectives were, in general terms, to find what were the determinants of Portuguese industrial innovation. The study aimed at finding answers for the following questions:

> What is the main determinant of Portuguese industrial innovation? Is it the political, economic, social or cultural institutional environment? Is it the strategy followed by the economic agents? Is it a combination of both? What is the relative importance of each factor?

In order to answer those questions we have grounded the analysis on a conceptual framework linked to evolutionary theories of technical and economic change and on systems theory, aside from recurring to other schools of thought such as theories of industrial innovation, organisational and management theories and the systems of innovation approach. Since the postulates of evolutionary theories explicitly consider the analytical distinction between the environment of a firm, the firm's internal characteristics and the conceptual framework to analyse the interactions between the two dimensions, it was particularly well suited to be applied in the present study.

In line with the research objectives stated above the study was divided in two parts, for analytical convenience. In the first part, after establishing the theoretical underpinning to consider the national environment as an object of study the characteristics of the environment were identified. For analytical purposes the analysis of the environment was made by subdividing the environment in three “sub-environments” or sub-systems, which were the economic system, the education system and the research system. Each sub-system was extensively described and analysed. Description and analysis were made simultaneously and interdependently. Description was deliberately oriented, emphasising facts, circumstances, interactions, which logically support the explanations or hypothesis the author exposed, and to which the author wanted to led its audience. Several explanations for several and multifaceted events, circumstances and historical processes were advanced. All of them, in one way or another, led to one end, one purpose. That of interpreting and comprehending, at a general but embracing level, the idiosyncratic Portuguese process of indigenous scientific, technological and technical development. In the second part, after establishing the theoretical underpinnings for considering the firm as an object of study, the internal characteristics of the firm were analysed. This analysis was based on interview-based case-studies of a sample of nineteen firms of the equipment goods sector. The results of those case-studies were extensively reported and analysed within the context of an evolutionary conceptual framework and a formal model that contributed to the explanation of the observed variation was developed and proposed.

In this concluding part we intend to bring together the two parts of this study, namely the conclusions reached in the analysis of the environment and the conclusions reached in the analysis of the firms. In order to do that we will make use of the model introduced in the last chapter and we will also introduce a conceptual approach which, combined with the previous model, will pave the way for explaining the interactions between the two levels of analysis, binding them together in a coherent whole, and ultimately answering the questions we have proposed at the beginning of this study. However, before we proceed, a note on the methodology is on order.

14.2 A note on the methodology

The methodology we used in the analysis and characterisation of the environment was archive and literature-based and had a strong historical perspective. The historical perspective was considered essential to explain the present condition of the system and hence the insistence on the approach. The present features of the educational system, the present structural characteristics of the industrial sector and the present knowledge level of the research system are all dependent upon initial conditions and their subsequent evolution, as we tried to prove in chapters 4 through 8. We believe that the conclusions we have drawn are strongly supported by quantitative or qualitative evidence presented by the literature to which we have referred in those chapters.

The methodology used in the analysis of the firms followed as much as possible the experimental-control methodology often used in the social sciences. However, there were some limitations in the methodology. One of those limitations was in the way in which innovative performance was defined and, consequently, in the way firms were grouped together. Some of the criteria, such as the opinion of the experts, were essentially subjective. However, there were problems in using purely quantitative indicators. Those problems were related to the deficiency of available quantitative data on innovation, such as firm's expenses in the several stages of innovation, or the percentage of sales of new products. Another problem was related to intrinsic limitations of the indicators. Many firms do not possess separate R&D departments, which does not necessarily mean that they do not perform R&D or innovative activities. The percentage of sales accounted for by new products can also be a problematic indicator if two firms at very different knowledge/technological levels are being compared. The definition of newness in this case is at the level of the firm and not at a higher level. As such it was not particularly useful for our purposes because it could mask important differences in the output of the firm. The conclusion we reached was that selected subjective criteria coupled and cross-referenced with other quantitative indicators (where available) constituted the best solution for choosing the sample and it was the one which gave more guarantees that the sample would be representative of the innovative level of Portuguese firms.

Another limitation related to the sources of information was the possibility of an eventual selection bias towards a sub-group of the population. This was so because of the characteristics of Portuguese society, namely the existence of a relatively strong social divide. One may conjecture if the sources of information provided by people related to trade journals or the sector association were not eventually biased towards the social segment to which they were familiar with. We think such bias is either not present or small because such information was confronted with other sources of a more universal (national) nature, such as R&D statistics as provided by the respective government office, and because, as the field study progressed and information from various social segments was collected, we realised that the initial information was quite accurate. The accuracy of such information was also related to the relatively small size of the country and of the sector.

Another limitation is related to the small size of the sample and to the issue of whether the population was sufficiently or accurately represented. We believe the method for choosing the sample was very closely related to a stratified random sampling procedure. Possible factors that may have distorted the randomness of the sample can be related to the sources of information on which we have relied, a problem to which we have already referred.

In spite of its small size we believe that the sample is a good representation of the population, because the population of capital goods producers (in a restricted sense, i.e., including only producers of machinery) is also quite small, according to Vasconcelos (1994), which identified a total population of approximately 330 firms (cf. chapter 3). On the other hand care was taken to emulate as much as possible the size distribution of the population. We must recall that almost 99% of the firms in the total sector population have less than 500 employees and 90% have less than 100 employees. As such our sample is also a reasonably good approximation of the total population.

14.3 The systemic approach

The system model proposed in Chapter 12 (cf. Figure 13) is one way to analysis the connection between the environment and the performance of the firms in the sample. The model help us in identifying the effects a particular higher level sub-system has on the other systems and on the main system (the innovation process at the level of the firm), or in other words, to detect the cause-effect relationships between the sub-systems, and to identify in what manner those cause-effect relationships affect the efficiency of the main system. We can make that exercise relying on the arguments advanced earlier on the main text and infer, in general terms, the impacts upon the individual firms.

For instance, it seems clear from the analysis of the education sub-system made in chapter 6 that the deficiencies that were identified, namely those related to an historical lack of investment in education activities and the accompanying lack of highly trained human resources, had enormous impact in terms of the contents and the availability of the “existing corpus of knowledge” in the Portuguese national system. Under the circumstances described earlier we would expect that the contents of that block would be deficient, weaker or outdated relatively to other systems where investment in the educational infrastructure was greater. This is so because under-investment implied deficiencies in terms of capital investment in pedagogical laboratories and equipment, for instance, or deficiencies in terms of the training of teachers. Systemic reasons and network externalities must also be considered. Failure to build a critical mass in terms of highly educated human resources implied deficiencies in terms of the possibilities of having a wide range of competencies within the borders of the (national) system. A diminutive number of educated people, aside from failing to provide such a broad range of competencies resulted, in the Portuguese case, in an excessive predominance of one educational paradigm or approach (namely literary studies; cf. chapter 6) relative to other alternative approaches.

What were the implications of these features for the firm sub-system? There were two orders of impacts. The first was a quantitative impact. The small number of qualified personnel implied that the availability of the “existing corpus of knowledge” for firms that had reached a bottleneck in their internal process of innovation and wanted to resort to existing competencies was severely limited. We would expect that in such circumstances the costs incurred in searching for such knowledge could be in many cases excessively high because of its scarcity, deterring many firms from making the connection with the external sub-system. They would then be confined to their own knowledge base, whatever that knowledge base was (in many cases diminutive, because the educational system itself suffered from under-investment and as such impeded wider diffusion of skills throughout the system). The other impact was of a qualitative nature. Even if the costs for finding and using existing knowledge were not great, there was a high probability that the quality of such knowledge was not the best, due to deficiencies in the way it was transmitted through the educational system, which suffered from under-investment in terms of its quality. Another qualitative impact was in terms of the alternatives that the firm sub-system would find in the “existing corpus of knowledge”. Probably, there was a restricted number of “search avenues” open to find a solution to the specific problem of the firm. Technical solutions would be heavily concentrated on a limited set of approaches with potential problems in terms of its efficiency, its adequacy or even its applicability.

Both order of impacts reduced, in general terms, the overall variability within the system and as such had a negative impact in terms of innovative potential of Portuguese firms. The fact that many firms found in this study did not possess highly trained personnel (cf. Table 53) or the fact that the educational level of a large proportion of production personnel was only at the elementary level (although no quantitative indicators were explicitly given considering that matter, we recall that only the firms in pair 6, i.e., the younger firms of the sample, showed an higher intensity of education at the secondary level amongst their production employees) are visible signs of the interactions between the sub-system “existing corpus of knowledge” and the sub-system of the firm. The better educational characteristics of the younger firms relative to older firms (that faced certain difficulties or rigidities in updating their work-force), not only at the shop-floor level but also in terms of intensity of graduate personnel at higher levels, may eventually reflect the impact of the recent historical developments of the educational system (in quantitative but also in qualitative terms).

Similar considerations can be made about the research sub-system analysed in chapter 7. The impact on the firm sub-system is even greater in the sense that the research sub-system suffered from even more deficiencies than the educational system, both at qualitative and quantitative level. The same two order of impacts described earlier regarding the educational system are also valid and applicable to the analysis of the impacts and the interactions between the "research" sub-system and the firm sub-system. Due to the historical characteristics and evolutionary features of the Portuguese research system the link between the firm block and the research block was rare or even non-existent. Firms resorted preferably and perhaps exclusively, and in many cases presumably with great difficulty, to the "existing corpus of knowledge". Thus the importance of external acquisition of technology for Portuguese firms and their general inability to evolve behind its mere application (for instance, by resorting to reverse engineer and incremental improvements). Not only there was not a public research system that could provide solutions to the technical problems of the firms, but also the firms themselves did not provide significant inputs, either in the form of financial inputs or physical inputs, to the research system. Only recently, specifically after the 2nd World War and the following period of accelerated economic growth described in chapter 5, which created the demand for a more elaborated and larger research system, can we see the links between the two sub-systems increase and the importance of external acquisition of technology decrease relative to past conditions. Even so, in the following three-decade long post-war period, the enlargement of the research system was done by concentrating resources in the state research laboratories, which were more concerned with technological services than with fundamental and applied research or technological development (cf chapters 5 and 7). In this sense, and in the context of our analytical model, the impacts of the stimuli provided by post-war economic growth in the creation of state research laboratories were to be felt more at the level of quantitative and qualitative improvement of the “existing corpus of knowledge” of the whole (national) system than at the level of the “research” system. Nevertheless, the “research” block was quantitatively and qualitatively improved, mainly by means of public resources but also by private (firm) resources, in spite of the diminutive overall commitment of resources. In spite of the new opportunities to link the firm sub-system with the research sub-system created by recent policies of public support and intervention in science, technology and industrial innovation (spurred by accession to EC in the 1980s; cf. chapters 5 and 7, specifically sections 5.5 and 7.8) the intensity and density of those links remained weak. On the other hand the intensity and density of relationships of firms and institutions or entities providing technical services has increased substantially, because the density of these institutions on the national system has also increased substantially (also spurred by accession to EC). This explains the general diminishing trend in the deficit of the balance of payments related to industrial engineering services (Banco de Portugal, 1998) and also gives context to an earlier observation (in chapter 8) predicting that it would be very difficult to find Portuguese firms with state-of-the-art and world-class innovative output.

The preceding analysis provides us with a sort of descriptive relational map of the environment and the firms, but it is somewhat arid as it respects the uncovering of the underlying deep factors that are behind the flaws of the system. The next sections will hopefully fill that hole.

14.4 The concepts of embeddedness and institutions

We said on the final lines of section 14.2 that a conceptual approach would be introduced which, combined with the extended chain-linked model, would provide the necessary tools for explaining the interactions between the system analysis and the firm analysis. That conceptual body is related to the notion of embeddedness as used by the so-called economic sociology school (Granovetter and Swedberg, 1992), a notion that is a consequence and a produce of the intellectual and academic unsatisfactory position with the classical and neo-classical approach to economic action.

This approach is in fact extremely influenced by, and we can even say that it is a contemporary continuation of, the so-called nationalist or historical school to which we have referred in Chapter 4, particularly as it refers to the inadequacy of the classical assumptions to deal with the complex intricacies and diversity of economic realities. In particular, it takes issue with the notions of efficiency and rational behaviour (or choice), arguing that economic action can not be divorced from other actions that enter into the realm of sociology, such as the notions of power, norms and values. As such, and at the limit, there is no such thing as a purely rational and efficient economic action in the classical or neo-classical sense because every or almost every economic action is constrained or influenced by sociological factors (or actions). Another recurrent concept of the school of economic sociology is the notion and emphasis on institutions, which is the main vehicle trough which macro-economic issues are addressed. Institutions are, on the one hand erected by the dynamics of individual or social groups actions, and on the other hand, determine the actions of individuals or social groups.

In short, economic sociology stands on the following core propositions: "1. Economic action is a form of social action; 2. Economic action is socially situated; and 3. Economic institutions are social constructions" (Granovetter and Swedberg, 1992, p.6). Those propositions are perfectly compatible with our theoretical approach, namely with the evolutionary perspective we have adopted, and with the systems of innovation approach, or in general, the systemic approach we have also pursued, and it is also in line with the historical perspective we have dearly impinged on this work. This conceptual tool is necessary to flesh out in its entirety Dosi's proposition mentioned earlier in page 190 (Dosi, 1994, p.159).

Relative to the notion of embeddedness proper, we shall introduce it and define it by resorting to the definitions advanced and used by Polanyi (1955), and Granovetter (1990). In Polanyi the notion of embeddedness is intrinsically linked with the notion of institution. For Polanyi, the economic process is not independent of the structure of a given society, rather the contrary, the structure of society gives meaning to the economic process:

> “ Nevertheless, reduced to a mechanical, biological and psychological interaction of elements that economic process (changes of location or appropriation of goods) would possess no all-round reality...[...]...In the absence of any indication of societal conditions from which the motives of the individuals spring, there would be little, if anything, to sustain the interdependence of the movements and their recurrence in which the unity and stability of the process depends...[...]...Hence the transcending importance of the institutional aspect of the economy...[...]...The instituting of the economic process vests that process with unity and stability; it produces a structure with a definite function in society ; it shifts the place of the process in society, thus adding significance to its history; it centres interest on values, motives and policy” (Polanyi, 1955, p.249-250)

From this propositions it follows the definition of the concept of embeddedness:

> “The human economy, then, is embedded and enmeshed in institutions, economic and non-economic. The inclusion of the non-economic is vital. For religion or government may be as important for the structure and functioning of the economy as monetary institutions or the availability of tools and machines themselves that lighten the toil of labour.” (Polanyi, 1955, p.250)

In view of the definition Polanyi proposes a way to look at or a strategy to follow regarding the study of economic action:

> “The study of the shifting place occupied by the economy in society is therefore no other than the study of the manner in which the economic process is instituted at different times and places.” (Polanyi, 1955, p.250)

Granovetter's approach is more refined and elaborated and methodologically grounded on social network analysis. It draws on fundamental propositions that were already referred to above, namely that:

> "(1) action is always socially situated and cannot be explained by reference to individual motives alone, and (2) social institutions do not arise automatically in some inevitable form but rather are socially constructed...[...]...The first proposition leads to...'the problem of embeddedness': the question to what extent economic activity is mediated by -or...'embedded in'-networks of personal relations. This discussion will lead ...into [the] argument about the 'social construction of economic institutions'." (Granovetter, 1990, p. 95-96).

Granovetter then proceeds with the definition and subdivision of the concept of embeddedness:

> "By 'embeddedness' I mean that economic action, outcomes and institutions are affected by actors' personal relations, and by the structure of the overall network of relation. I refer to these respectively as the relational and the structural aspects of embeddedness." (Granovetter, 1990, p.98).

It seems that the notion of structural embeddeness seems quite similar to the meaning ascribed by Polanyi to the same term. It is also the meaning of the term "embeddeness" to which we shall resort as we proceed in our analysis of the Portuguese system and firms and their mutual relationships and their pattern of interactions. Of course that in our analysis we shall not address preferentially economic actions and outcomes but rather we will pragmatically extend the concept of embeddedness to gain insights on the outcomes of the process of Portuguese indigenous technological innovation, which is our main concern here.

We have mentioned that the notion of embeddedness is closely related to that of institutions, so we must be more precise of the meaning we shall ascribe to the term. In our analysis we shall presuppose the sociological meaning of the term, which, according to the review of Edquist and Johnson (1997), is defined in the following manner:

> "Institutions are common habits, routines, established practices, rules, or laws that regulate the relations and interactions between individuals and groups" (Edquist and Johnson, 1997, p.46)

In the same review, the distinction between organisations and institutions is based on the arguments of North (1990): "A crucial distinction....is made between institutions and organisations...Conceptually, what must be clearly differentiated are the rules from the players." (as cited in Edquist and Johnson, 1997, p.47). Specifically, "...It is important to note that organisations are formal structures with an explicit purpose and they are consciously created. They are players or actors. In contrast, institutions may develop spontaneously and are often characterised by a specific purpose." (Edquist and Johnson, 1997, p.47). The authors further argue that "...Organisations are strongly influenced, coloured and shaped by institutions. Organisations can be said to be 'embedded' in an institutional environment or set of rules. This include the legal system, various norms, standards, etc., which influence all organisations of a certain kind, (e.g., all firms in a country)." (Edquist and Johnson, 1997, p.59).

Granovetter further adds "...it is impossible to understand an institution adequately without an understanding of the historical process in which it was produced" (Granovetter, 1992, p. 17). In order to include the historical dimension into the study of institutions the concept of path-dependence, generally associated with David (1985) and Arthur (1988), is used. Granovetter argues hat the same concept can be used to explain the origins, building up and consolidation of institutional frameworks and it can be eventually more useful than the explanation based in terms of efficiency of institutional set-ups.

In the following analysis we shall rely heavily on this conceptual framework, to make a comprehensive review of the main arguments of the thesis. What has been said on the previous chapter must be understood in relation to these additional concepts that complement but are nevertheless intrinsic part of the whole conceptual framework we have been using throughout the thesis. The specific way firms have evolved, as described in Part III, are heavily influenced by the institutional set-up of the country. From the extensive analysis that has been made some features of the institutional set-up (the environment) are obviously related to the specific trajectory of the firms. We shall try, in the following sections to highlight those relationships and thus conclude our argument and provide answers to those parts of the research questions, which were left unanswered. Unlike the habit of this thesis, a last short section will look towards the future, and point out some policy implications.

14.5 The influence of culture on the trajectory of Portuguese indigenous innovation

Since the notion of embeddedness is so closely related to that of cultural values, we shall start with reference to the study of the cultural environment addressed in Part II, and specifically in Chapters 6 and 7. There we referred to two great cultural influences: the Hellenic body and approach to “scientific” knowledge and in particular to the predominance of the Aristotle school, and the pervasive influence of Catholic values and norms. We further added that these two great cultural dimensions were in fact supportive of each other and mutually reinforcing. These two institutions (they are institutions in the meaning we have ascribed to them) were determinant, for a long time, in establishing an intellectual pattern of individual search and inquiry regarding the natural and exact sciences which in turn was determinant in defining the trajectory of indigenous innovation in Portuguese society. And that trajectory was, as we saw earlier, marked by a late-coming of Portuguese society as a whole and firms in particular, in embracing the new scientific methodology and paradigm that came out of the enlightenment.

The reason for that delay is related to the strength of the catholic institution and the innumerable points of conflict between this institution and the new Cartesian and rationalist scientific method and philosophy, and its extreme reluctance to abandon the Aristotelian elements that were deeply embedded in organisations related to the production, teaching and diffusion of knowledge. (We shall recall that schools from the primary to higher secondary level were heavily dominated by the church, and the university was also heavily influenced by these two institutions and had no alternative opponents until the early 1900s).

The two philosophies were actually quite coherent with one another. Aristotelian philosophy has perspectives that are dear to the catholic and Christian perspectives on the notion of the unity of matter as created by God (and are at odds with the new atomistic perspectives).

The consequences of the delay of Portuguese society as a whole in adapting or altering its institutional set-up and in adhering to the rationalist waves of science were multiple, but obviously the main ones were the barriers it created to devise and set-up organisations which embodied the new institutions, i.e., the new set of rules, norms and standards most commonly referred to as the scientific method. Such barriers to the creation of new organisations that embodied the new institutional set-up slowed down the diffusion throughout the individual members of society of the principles and fundamentals of the methodological approach and concepts of the new sciences and their potential of applications in industrial devices or in consumer products. In other words, the knowledge background necessary to successful technical accomplishment of the design and production of new technology were deficient or non-existent in a large percentage of the members of society, and were extremely difficult to acquire due to its scarcity. Moreover it delayed the establishment of a new mental attitude towards the resolution of technological problems, namely what we have called the intellectual pattern of search, inquiry and problem-solving.

Deriving from this situation, the development of a technological infrastructure occurred slowly and intermittently and only very recently. We use the concept of technological infrastructure proposed by Justman and Teubal (1995): "...a set of collectively supplied, specific, industry-relevant capabilities, intended for several applications in two or more firms or user organisations. They are embodied in human capital (both formal education and experience, and include also elements of physical capital (such as instrumentation) and knowledge." (Justman and Teubal, 1995, p. 260). An infrastructure with these characteristics surge only after the 2nd World War, and then most of its activity was oriented towards the routine provision of technical services.

14.6 The economic structure of society

The conservative influence of the cultural institutions referred to in the previous sections were also responsible for the shaping of the socio-economic environment of the country, which was characterised by the rigidity of two main factors of production, namely land and labour, whose conditions were regulated by laws, values and norms that draw heavily on the medieval tradition and organisation of economic activity. The transition towards a situation whereby values and norms that were typical and characteristic of a new institution, the market, was slow and lasted all the 19th century and early 20th century, and even so it was never fully realised. The early 1900s was perhaps the historical period where the market institution was more fully realised but it soon gave way, in the 1920s, to a corporatist regime that practised state intervention at all levels of economic activity. In fact, the corporatist regime surged as a socially demanded response to the advancements of the market institution at the time and to the consequences it brought in terms of its negative impacts on social stability (namely as it regards industrial labour dislocation brought about by unequal competitive positions of small artisans and modern factories, and market demands on the landed). Only after 2nd World War did Portuguese society adhered in a more complete way to the market institution and even so in a most prudent way. Enthusiastic commitment to the market institution came effectively by the time of Portugal's accession to the EEC in 1986, but even then it was constrained by the socialising dimensions inherent to EEC's policies and to the various safeguarding mechanisms of national production and economic structure that were implemented when accession occurred.

This situation, characterised by a relative distancing from market institutions, and from the competitive standing that such an institution implies, and specifically as it regards the competition for the new product, the new process or the new organisation, did not led the individual members of Portuguese society to perceive or to consider technological innovation as a necessity. That, coupled with the scarcity of technological infrastructures and its inadequacy to the new scientific paradigm, arising from the situation described earlier, mutually reinforced the laggard, imitative, and adaptive character or attitude towards technical change and its use in productive activities.

14.7 Sociological considerations

Mention was made throughout the main text of the social divide of Portuguese society. The origins for that are difficult to discern but certainly one of the causes of its aggravation, if not of its origin, can be found on the evolution of the economic organisation of society and on the unbalanced attributes of the education system. What is worth emphasising is that the social divide lasted, although abated, until the present days. In terms of institutional analysis and its impact in terms of innovation the main consequences of the prevalence of such a trait is the erection of several communication barriers between the main actors that intervene in the process of innovation, namely the firms, the research institutes, the universities and other technological infrastructures. Whatever the social and psychological factors those barriers are composed of, the fact is that the consequences are serious flaws in terms of flows of information between the actors with the result that the process of innovation is either hampered right from the start or it is probable that it encounters serious difficulties along its trajectory. Notice that many firms in the sample had few or none institutional contacts.

14.8 The political dimension

It is difficult to analytically differentiate the political institutional dimension from the cultural, economic and social institutional dimensions, but there are factors that can be better explained by resorting to this dimension, we will suggest that the main impact of the political institutions are at the level of the degree of political centralisation of the country and at the level of the educational system. The political system has strong centralising features. The tendency to centralise power at the expense of county or municipality powers has been for quite some time a distinctive feature of the country. Geographically, the unity of the country was clear and in military terms, relatively easy to maintain, as the country had only borders with one country, namely Spain. This administrative centralising tendency and the unquestionable unity of the country are possibly factors that explain the lack of necessity of the state to adopt other methods to unify the country and the nation, namely by virtue of the education and indoctrination of its citizens. This lack of necessity of universal education explains the large illiteracy rate that remained until quite late in the 29th century (and even today, according to OECD standards). On the other hand, the centralising administrative feature of the country proved itself also a barrier the diffusion of technological and scientific capabilities throughout the country due to the tendency to centralise educational, scientific and technological infrastructures near the political centres.

14.9 Environment and firms

We shall now use the distinction between structural embeddedness and relational embeddedness (cf. Section 14.3) to highlight the relationships between the institutional features and the characteristics of the firms.

The concept of structural embeddedness is particularly useful to explain certain general characteristics of the firms we have analysed in Part III. All the institutional apparatus we have described and on which the firms are embedded explain several characteristics that are common to all the firms in the sample. The Aristotelian approach to knowledge, the Catholic philosophy and heritage, the subservience of the educational system to this paradigm, the lack or weakness of a critical attitude of opposition and intellectual confrontation, the scarcity of educational establishments and technological infrastructures, the social divide and the accompanying deficiency in terms of flows of information, e.g., the more or less widespread scarcity of a scientific and knowledge base and critical mass are all structural characteristics that are behind the imitative and adaptive attitude of the firms analysed in the sample. It is remarkable to note that all the firms in the sample introduced quite late technologies such as pneumatics and/or hydraulic devices and electric and electronic devices. The gap is particularly visible as it relates the use of pneumatic/hydraulic devices in machines. Their usage became quite common since the early 1900s in other developed countries. However, almost all of our firms (namely those that are oldest) started to use them only after the second half of the 20th century. The gap is shorter for the electronic/electric devices but it is still considerable, taking into account that the use of electrical devices in machines became also quite widespread during the early 1900s. The new firms, created in the mid 1980s, facing an institutional and organisational environment substantially different from the older firms acted quite differently, introducing from the very beginnings, advanced technological devices. However, they remain imitative and adaptive, although their action was guided by the notions of quality and constant improvement. They were not truly original, in the sense that they did not develop substantially different devices, and did not even use the latest techniques available and tested in machine tools (such as laser devices and others) and as such there was still a gap, although it became smaller. We do not want to stretch this argument too far. As it was said, the institutional and organisational set-up of the country is nowadays substantially different, namely as it respects the intellectual adherence to the scientific paradigm, the diffusion of education, scientific knowledge and technological skills. Under the present conditions, there is room for truly original and innovative outcome although it will be probably be a very rare and circumscribed event.

14.10 Firms and other firms

The concept of relational embeddedness is particularly useful to explain variation among firms embedded in the same institutional set-up and facing up, apparently, the same constrains and opportunities. If there are differences between the innovative outcome of firms in our sample it becomes clear that the institutional environment is not the sole factor in explaining all the characteristics of the firms. In fact, firms face different environments, because the environment itself is multifaceted (we have already proposed this approach regarding the analysis of pair 7 in Part III) and because the firms, in a certain sense, create their own environment. In firms were the personnel is subject to higher levels of education, the technical possibilities and the horizons faced by that firm are completely different from firms were the education level is lower. In other words, the environment is different, and this is only at the level of possibilities, of potential. In real terms, the social networks on which each firm is embedded, due to its different educational achievements and its different capabilities in terms of mastering technical and scientific languages are quite different. The consequence is that there are differential capabilities in terms of being able to internalise the factors identified in Part III and described in Table 48. For instance, the contrast between the social connections of the two firms in pair 1 could not be greater. The same is true for the firms in pair 8. The educational attainment level in both cases is quite different. However, even in those cases where the level of educational attainment is comparable, there are differences in innovative outcomes due to qualitative differences in terms of relational embeddedness. Such is the case of the firms in pair 6, the youngest and perhaps the most innovative firms of the sample. Both firms are managed by highly trained people with close links to university, and employ within their ranks at least people with complete secondary education. However, one of the managers is connected to an university with an established reputation in mechanics and his main client is a demanding multinational car manufacturer. The other manager is linked to an university with no special reputation in the field of mechanics and his clients are less demanding manufacturers of taps, bicycles and other fine metallic structures or apparatus for civil construction. The knowledge and capability contents implicit in each network determines to a great extent the innovative outcome or performance of each firm, i.e., its ability to incorporate successfully the determinant factors we empirically identified. In general, the same line of reasoning is true for each pair of firm analysed. The richer and varied the social network the firm is embedded in (through its personnel), the better is its innovative outcome.

14.11 A final remark: policy implications

According to the structural characteristics we have pointed out, it seems that at this point of the development of the institutional set-up of the country the need for policy actions lies more on long term emphasis on the intangible side of the infrastructure than on the tangible side. The latter still needs some additional efforts, in particular as it respects the educational infrastructure, but probably as much important as physical investment is the need to reformulate curricula and methodology (this observation is probably valid to all teaching levels). In particular, great attention should be paid to the secondary level, which seems to be the weakest part of the educational system.

Large investments in physical infrastructure were made during the last years. Following the taxonomy and the conceptual framework proposed by Justman and Teubal (1995) for analysing technological infrastructure (TI) building, one can say that the basic TI, due to the developments of the last ten years, reached a minimum critical mass, although it still suffers from a high degree of centralisation. This involved a co-operative public and private commitment, and we are not wrong to assume that the public initiative acted as catalyst to the process (which, according to Justman and Teubal, was an expected and probably necessary intervention, due to the special demand characteristics and the potential absence of market for these kinds of services). The market building process in basic TI seems to have developed satisfactorily, and many technological centres seem to be on the verge of running with a profit. As it regards advanced TI the situation is much more modest. There is apparently one or two initiatives which we could categorise under the term of advanced TI, involving information technologies and research consortia between a research institute, a telecommunications company and an electronics firm. Most of the interactions between TI and users (firms) are at the level of the "...bread and butter problems facing firms..." (Justman and Teubal, 1995, p.266), involving generally little R&D. The amount of R&D involved in this co-operative effort depends on the type of industry and the type of organisation involved. Typically, little R&D is involved in the output of technological centres, while those of research institutes (often linked to universities) involve a greater component of R&D. State research laboratories have a balanced evenly split output in terms of R&D content (with emphasis on D). Typically again, the links of pharmaceutical industry with TI are more research oriented than the links of the textile industry or even the mechanical industry. On the whole, the demand for TI services is still quite underdeveloped and there seems to be a need to implement policies that can stimulate this interaction. This is an important structural feature, as mentioned above, which probably needs to be tackled through state mediation.

There is apparently the need to implement what Teubal (1997) calls Horizontal Technology Policies (HIPs), i.e., a set of measures that promote endogenous generation of "socially desirable technological activities" (SDTA). According to Teubal (1997) a typical path of SDTA diffusion is associated with three kinds of projects: "A routine set of SDTA projects with high appropriability, whose implementation has been substantially endogenized; an emerging group of 'complex' projects involving significant additions to technical and techno-economic knowledge; a group of 'strategic' SDTA projects that government, due to the learning associated with the above, can co-ordinate and orchestrate" (Teubal, 1997, p.1172). The Portuguese system is, to a large extent, still at the first stage of this path. There is also the presence of the second category of projects, but they are still at a very incipient stage. The academic community is probably more committed and advanced in that respect than the industrial community, which is logically the main target of these policies. There have been some government initiatives that tried to stimulate the intervention of industry in more complex projects and initiatives, many of them using the EU research programs as the vehicle for that end. Tax incentives have also been recently linked to industrial R&D. But the results have been far from satisfactory, if we measure results by the complexity of the projects that have been implemented and the level of committed R&D resources. It seems that the main task of the government is to insist on this kind of policies, and in particular at the second stage of the proposed diffusion path, reinforcing the still weak ties between the several actors of the system and enhancing demand for services with higher R&D contents. Commitment and stronger encouragement to participate in EU R&D programmes should continue. Priority should be given to the financing of co-operative projects or projects in consortia. Another way is to change the organisational configuration of some technical activities or centres with a strong orientation towards the provision of industrial services and presently affected to universities. This should be done in parallel with increasing efforts of decentralisation of TI which, in spite of recent efforts, are still unevenly distributed throughout the country. Ancillary technical information services, such as patent, information and brokerage services, should also be more decentralised and reinforced. However, we believe that the communication problem will only be satisfactorily resolved once the majority of the actors speak the same language and at the same level, i.e., when the education system has made its levelling mission.

In spite of the fact that, apparently, the institutional, or shall we say more appropriately, the organisational set-up is in place, it does not necessarily mean that the interactive and co-operative dimension of the process follows, even with government intervention. And this is because one can not divorce institutional set-up from its historical and cultural context. The way that institutions run and function are path-dependent, are idiosyncratic, are socially as well as economically determined, and as such their outcomes, in terms of innovation producing, differ from country to country. It may be not enough to support organisational bodies similar to those of other countries if the broader institutional set-up (that includes law, culture and values) prevents them from fulfilling the function they were supposed to perform. If policy measures are to be taken they must necessarily take into account the specificity of the institutional set-up and their (co-) evolutionary characteristics.

ANNEX A. THE PRODUCT LINES AND THE SIZE OF THE FIRMS IN THE SAMPLE

	"Average" group				group			
Pair	**Name**	**Previous products**	**Present products**	**Size**	**Name**	**Previous products**	**Present products**	**Size**
1	Arvorense	Agricultural machinery	Lorry bodies, agricultural machinery	30	Herculano	Agricultural machinery	Agricultural machinery	200
2	Vima	Dumpers	Conveyors, dumpers	60	Mano	Conveyors	Conveyors	110
3	Avense	Looms	Components for textile machinery, textile machinery, other machinery	23	Industrial	Looms	Components for textile machinery, textile machinery	40
4	Frama	Wood-working machine-tools	Wood-working machine-tools	82	Pinheiro	Wood-working machine-tools	Wood-working machine-tools	290
5	Mecano-Textil	Textile machinery	Textile machinery	140	ACL	Looms	Hydraulic components, lifting gear, presses, textile machinery	70
6	Maquisis	Metal working tailor-made machine-tools	Metal working tailor-made machine-tools	19	Seri	Metal working tailor -made machine-tools	Metal working tailor-made machine-tools	16
7	Sersan	Machine-tools for the cork industry	Machine-tools for the cork industry	25	Prensarte	Machine-tools for the cork industry	Machine-tools for the cork industry	19
8	Diarroca	Presses, components	Components, presses	25	Adira	Presses, press brakes And guillotine shears	Press brakes, guillotine shears, presses	250
9	Mecver	Presses, components	Components, presses	49	Guifil	Moulds, presses, press brakes, guillotine shears, lathes, other	Press brakes and guillotine shears	103
10					Efacec	Electric power stations	Electric power stations, electric and electronic machinery, software	2500

Note: Size is measured by the total number of employees.

ANNEX B. THE INTERVIEW TOPICS AND THE AIDE-MÉMOIRE

B.1 The objectives behind the interview topics

1. Date of start-up

2. Ownership status

Objectives:

To identify equity composition as share of total capital and its influence on innovative performance. To look for differences on: independent company or subsidiary, majority of capital owned by nationals or foreign companies, family owned or owned by a society of shareholders.

3. A historical perspective of the firm

This part of the interview will serve as a preliminary introduction to the more detailed aspects that will later be asked for. It will act as a "situating" exercise, and a way to have a comprehensive perspective on the firm. With the purpose of facilitating analysis of the firm trajectory the history of the firm will be divided in defined periods. The criteria for setting the periods will be subjectively dictated by the interviewee and can change depending on the firm.

4. Initial product line/range and its subsequent evolution until this day

Objectives:

To assess the output of the firm and how it has evolved over time, based essentially on "peer" review.

Contents:

This topic is a description of the types of products the firm is engaged in. Information on the degree of its technological content will be based on the following:

-self-assessment by the producers

-evaluation by other producers of similar types of products

-evaluation by university or research organisations experts

-evaluation by users

-the industry literature

-patents

5. Factors deemed to have a direct relation to innovative performance:

a) Technical knowledge

- of the engineers or scientists
- of the technicians
- of the production staff

b) Demand for the product(s)

- niche
- import-substitution
- competing
    - -on what grounds? Price, quality or performance, service
    - with whom? Domestic or foreign competition

c) Source of technology and its impact

- internal
    - R&D department
    - production engineers
    - technicians
    - marketing staff
    - other
- external
    - customers
    - suppliers
    - strategic alliances
    - licence
    - imitation

universities

research laboratories

other research institutes

- impacts

future innovations

search activities

ongoing R&D

instrumentalities

production

technical backup

d) customers

- sectoral characterisation and composition

- domestic composition

- foreign composition

5a.

Objectives:

To capture a dynamic picture of the internal capabilities of the firm and its evolution over time and to establish relationships between its output and its internal capacities. A map of its competencies vs. its actual or future needs could be drawn.

Contents:

This topic intends to capture both a qualitative and a quantitative picture of the technological capacity of the firm embodied in human resources. Quantitative measures will be:

-the number and share of postgraduates and graduates

-the profile of the graduates and postgraduates

-the number and share of skilled technicians (at least a vocational secondary level course)

-resources devoted to R&D

Qualitative information will be:

- the differential importance of each group relative to the set-up, improvement or development of products, and their own relative capability compared with similar groups. It will be a subjective picture relying mainly on self assessment and cross comparison of opinions between the groups. If possible a qualitative assessment by using a discrete scale will be used.
- comparison over time, assessing the relative importance of each group as time goes by. No time periods will be imposed. They will show up according to the specific dynamics of the firm.

5b.

Objectives:

To assess the impact on the innovative capacity of the firm of several variables related to market conditions. To classify entrepreneurial behaviours. It could be a useful criterion for classifying firms.

Contents:

This topic seeks to ascertain which factors were the most important to the dynamic set-up, improvement and development of products. A discrete scale as well as qualitative descriptions will be used. Comparison over time, assessing the relative importance of each group as time goes by. No time periods will be imposed. They will show up according to the specific dynamics of the firm.

5c.

Objectives:

To scrutinise the ways in which firms obtain information, and to assess the impact of each source of information on the innovative behaviour of the firm.

Contents:

The topic intends to assess qualitatively and quantitatively the importance of each possible source of knowledge, ideas or physical inputs to the innovation process inside the firm, using the Faulkner (1994) framework. Comparison over time, assessing the relative importance of each factor as time goes by. No time periods will be imposed. They will show up according to the specific dynamics of the firm.

5d.

Objectives:

To see if differential patterns in sectoral technological dynamics of users are important in terms of the firm/sector own technological dynamic.

Contents:

Quantitative measures of patterns of exports and sales. Identification of customers.

6. Type of production equipment

Objectives:

To assess the importance of equipment modernisation on the general attitude of the firm towards innovation and the importance attributed to it.

Contents:

Distinction between mechanic, semi-automated and automated equipment. Additional software and hardware systems such as CAD, CAM, CIM.

7. Finance

Objectives:

To identify the means by which funds for investment are acquired, e.g., own funds, borrowing or public offers. Identification of difficulties and barriers associated and their impacts on innovative behaviour.

8. Organisation and management

Objectives:

To identify the impacts of management practice and philosophy on innovative behaviour.

Contents:

A qualitative dynamic description and assessment of the various aspects of organisation and managerial decisions.

8a.Functional lay-out. Addresses the type of organisation structure that prevails. Function or market oriented. Existence of a separate R&D department. Existence of quality control laboratories.

8b. Decision-making. Location of the critical decision-making and patterns of authority (paternalistic, autocratic, democratic, co-operative). Patterns of strategy making (long-term vs. short-term). Co-operation, association and joint-ventures (With whom? How many? Why?).

8c. Managerial techniques. Related to 5b but trying to get some more detail. Planning, information flows, work assessment, training.

8d. Marketing. Importance of marketing. Marketing techniques. Distribution channels. Expenditures.

8e. Internationalisation. Which forms are adopted, if any, and why.

9. External conditions

9a. Government influences

Objectives:

To ascertain if government policies had any impact on the innovation rate and/or direction of the firm and to try explanations on when, why and where those impacts occurred.

Contents:

- policy
- government contracts or demand
- direct financial support (subsidies, taxation)
- indirect financial support (tariffs, trade barriers, investment barriers)

9b. General institutional environment and its impacts

Objectives:

A qualitative dynamic picture of the possible influences of other environmental conditions. Self assessment by interviewees. Possible a-posteriori construction of a qualitative table based on systematisation of subjective opinions, which could be used for quantitative analysis. Variables most looked for are:

-regulations and laws

-supply of human resources (managerial and technical)

-supply of technical services

-supply of financial services

-supply of consultants

10. A historical account of the most important innovation (or the most significant failure) and how it came about.

Objectives:

Useful for looking at the way problem solving is conducted and at the distinctive way the firm acts, and to complement the quantitative and fragmented part of the interview.

B.2 The aide-mémoire or the final questionnaire

I General Information

1. Name of company:..

2. Date of start-up:...

3. Number of employees:

Time period 1:_____________

Time period 2:_____________ etc.

4. What is the equity distribution of the firm?

Time period 1:______________

Time period 2:______________ etc.

II A historical perspective on the firm

This part is directly related to topic 3.

III Technological factors

Part III is directly related to topic 4 (questions 5, 6 and 7), topic 5a (questions 8a, 8b, 9 and 10), topic 5b (question 11), topic 5c (questions 9 and 10), topic 5d (question 12), topic 6 (questions 13a, 13b and 14), topic 7 (question 15).

5. What was the initial product or product line at the date of start-up of the company? Give no more than five products/product lines. Place the products by descending order of importance (in terms of sales).

1:_________________________

2:_________________________

3:_________________________

4:_________________________

5:_________________________

6. Did the firm diversify into other products or product lines?

No. Continue with next question.

Yes. Indicate, by descending order of importance, in terms of sales, the five main new product/product lines:

1:____________________________

2:____________________________

3:____________________________

4:____________________________

5:____________________________

7. Describe the main improvements on the main five product/product lines since their introduction in the firm. If possible, include sketches and drawings of the products.

Product line 1:____

Product line 2:____

Product line 3:____

Product line 4:____

Product line 5:____

Note: A taxonomy to follow while answering this question:

- mechanical improvements
- change in design
- new mechanical components
- new electric components
- new electronic microprocessor components
- other

8a. Indicate the number and share relative to total employment of the following categories of employees.

	Time period 1		Time period 2		etc.
	No.	%	No.	%	
graduates with technical functions					
graduates with administrative functions					
technicians with secondary level course					
technicians with a vocational secondary level course					
employees subjected to training courses					

8b. Indicate the profile of your graduates.

9. Indicate the importance of each functional group, as a whole, to the process of in-house development of new products or improvement of existing ones. Use the scale shown below.

Scale: 1-insignificant 2-slightly significant 3-moderately significant 4-very significant 5-crucial

	Time period 1	Time period 2	etc.
Researchers			
Engineers			
Technicians			
Workers			
Others			

10. Indicate the importance of the following sources of innovation on the indicated innovative activities using the scale shown below.

Scale: 1-insignificant 2-slightly significant 3-moderately significant 4-very significant 5-crucial

	Internal Source					External Source						
Impact on:	R&D Dpt.	Engineers	Techni.	Marketing	Other	Customers	Suppliers	Imitation	License	Alliances	Literature/Fairs	Research lab.
Universities/PNP												
1)Future innovations												
2)Search activity												
3)Ongoing R&D												
-Underpinning knowledge												
4)Instrumentalities												
-R&D procedures												
-Skills in experimentation and testing												
5)Production												
6)Technical backup												

11. Indicate the importance of the following market conditions on the development or improvement of products, using the scale shown below.

Scale: 1-insignificant 2-slightly significant 3-moderately significant 4-very significant 5-crucial

	Time period 1	Time period 2	etc.
domestic competition			
competition on international markets			
import substitution			
competition based on price			
competition based on quality, performance			
competition based on service			
Other (specify)			

12. Who were and are your main customers? Indicate the sector and the share of firm sales, in descending order of importance.

Time period 1

Product	Name of customer	Sector	Share	Market (domestic or foreign)
1		____%		
2		____%		
3		____%		
4		____%		
5		____%		
		100%		

etc. For additional time periods

13a. Indicate the type of production equipment utilised by the firm and the relative share (by number of machines) of each type of equipment.

	Share of total equipment production		
	Time period 1	Time period 2	etc.
manual	___%	___%	
semi-automated	___%	___%	
automated	___%	___%	
	100%	100%	

13b. Describe the main improvements on your production equipment.

1:______________________________

2:______________________________

3:______________________________

4:______________________________

5:______________________________

Note: A taxonomy to follow while answering this question:

- mechanical improvements
- change in design
- new mechanical components
- new electric components
- new electronic microprocessor components
- other

14. Indicate the existence or non-existence of the following types of production aides. Answer yes or no.

	Time period 1	Time period 2	etc.
CAD			
CAM			
CIM			

15. When investment is needed to develop or improve new products, from where does the funds come?

	Time period 1	Time period 2	etc.
Own funds	___%	___%	
Borrowing	___%	___%	
Public offers	___%	___%	
	________	________	
	100%	100%	

IV External factors

Part IV is directly related to topic 9.

16. Government influences. Indicate the importance of each factor on the rate and direction of innovation activities within the firm (for each time period).

Industrial policy

Economic and fiscal policy

Government contracts or procurement

Direct financial support (subsidies, taxation)

Indirect support (tariffs, trade barriers, investment barriers

Others (specify)

ANNEX C. TABULAR AND GRAPHICAL REPRESENTATION OF THE EMPIRICAL RESULTS

C.1 TABLES OF FREQUENCIES

C.1.1 Tangibles

Table 55. Table of frequencies of the variables: tangibles.

VARIABLE	VARIABLE CATEGORY	AVERAGE GROUP		INNOVATIVE GROUP		TOTAL SAMPLE	
		Group count	Group percentage	Group Count	Group percentage	Group Count	Group percentage
Existence of automated Equipment	No	6	66.7	1	10.0	7	36.8
	Yes	3	33.3	9	90.0	12	63.2
	Group Total	9	100.0	10	100.0	19	100.0
Predominance of old machines	No (50% or less)	4	44.4	9	100.0	13	72.2
	Yes (50% or more)	5	55.6			5	27.8
	Group Total	9	100.0	9	100.0	18	100.0
Improvements in Production machinery	No	7	87.5	2	20.0	9	50.0
	Yes	1	12.5	8	80.0	9	50.0
	Group Total	8	100.0	10	100.0	18	100.0

C.1.2 Intangibles

Table 56. Table of frequencies of the variables: intangibles.

VARIABLE	VARIABLE CATEGORY	AVERAGE GROUP		INNOVATIVE GROUP		TOTAL SAMPLE	
		Group count	Group percentage	Group Count	Group percentage	Group Count	Group percentage
Use of CAD	No	7	77.8	1	10.0	8	42.1
	Yes	2	22.2	9	90.0	11	57.9
	Group Total	9	100.0	10	100.0	19	100.0
Use of CAM	No	9	100.0	5	50.0	14	73.7
	Yes			5	50.0	5	26.3
	Group Total	9	100.0	10	100.0	19	100.0
Internal quality control Laboratory	No	8	88.9	2	20.0	10	52.6
	Yes	1	11.1	8	80.0	9	47.4
	Group Total	9	100.0	10	100.0	19	100.0
Existence of graduate Personnel	No	4	44.4	1	10.0	5	26.3
	Yes	5	55.6	9	90.0	14	73.7
	Group Total	9	100.0	10	100.0	19	100.0
Type of training	Only internal	7	77.8	2	22.2	9	50.0
	External courses	2	22.2	3	33.3	5	27.8
	Training plan			4	44.4	4	22.2
	Group Total	9	100.0	9	100.0	18	100.0
Separate R&D Department	No	7	77.8	2	20.0	9	47.4
	Yes	2	22.2	8	80.0	10	52.6
	Group Total	9	100.0	10	100.0	19	100.0

C.1.3 Management

Table 57. Table of frequencies of the variables: management.

VARIABLE	VARIABLE CATEGORY	AVERAGE GROUP		INNOVATIVE GROUP		TOTAL SAMPLE	
		Group count	Group percentage	Group Count	Group percentage	Group Count	Group percentage
Main source of funds for Investments	Own funds	8	100.0	7	70.0	15	83.3
	Borrowing			3	30.0	3	16.7
	Group Total	8	100.0	10	100.0	18	100.0
Receiver of subsidies	No	7	87.5	2	20.0	9	50.0
	Yes	1	12.5	8	80.0	9	50.0
	Group Total	8	100.0	10	100.0	18	100.0
Type of strategy	Short term	6	75.0			6	33.3
	Visionary	1	12.5	3	30.0	4	22.2
	Medium term formal planning	1	12.5	2	20.0	3	16.7
	Long and medium term formal planning			5	50.0	5	27.8
	Group Total	8	100.0	10	100.0	18	100.0
Approach to product design and Problem solving	individual machine	9	100.0	6	60.0	15	78.9
	integrated approach			4	40.0	4	21.1
	Group Total	9	100.0	10	100.0	19	100.0

C.1.4 External stimuli

Table 58. Table of frequencies of the variables: external stimuli.

VARIABLE	VARIABLE CATEGORY	AVERAGE GROUP		INNOVATIVE GROUP		TOTAL SAMPLE	
		Group count	Group percentage	Group Count	Group percentage	Group Count	Group percentage
Existence of exports	No	6	66.7			6	31.6
	Yes	3	33.3	10	100.0	13	68.4
	Group Total	9	100.0	10	100.0	19	100.0
Importance of external Competition	insignificant	7	77.8	2	20.0	9	47.4
	slightly significant						
	moderately significant	1	11.1	2	20.0	3	15.8
	very significant			2	20.0	2	10.5
	crucial	1	11.1	4	40.0	5	26.3
	Group Total	9	100.0	10	100.0	19	100.0
Type of domestic Customer	regional firms	4	44.4			4	21.1
	any domestic firm	5	55.6	4	40.0	9	47.4
	large innovative firms			6	60.0	6	31.6
	Group Total	9	100.0	10	100.0	19	100.0
Competition based on quality and Performance	insignificant	1	11.1			1	5.3
	slightly significant						
	moderately significant	4	44.4			4	21.1
	very significant	2	22.2	6	60.0	8	42.1
	crucial	2	22.2	4	40.0	6	31.6
	Group Total	9	100.0	10	100.0	19	100.0

C.1.5 External sources of knowledge

Table 59. Table of frequencies of the variables: external sources of knowledge.

VARIABLE	VARIABLE CATEGORY	AVERAGE GROUP		INNOVATIVE GROUP		TOTAL SAMPLE	
		Group count	Group percentage	Group Count	Group percentage	Group Count	Group percentage
Impact of fairs on future innovations	insignificant	5	55.6			5	31.3
	slightly significant			1	14.3	1	6.3
	moderately significant	3	33.3	3	42.9	6	37.5
	very significant			3	42.9	3	18.8
	crucial	1	11.1			1	6.3
	Group Total	9	100.0	7	100.0	16	100.0
Impact on scrutiny by suppliers	insignificant	3	33.3	6	85.7	9	56.3
	slightly significant	2	22.2	1	14.3	3	18.8
	moderately significant	1	11.1			1	6.3
	very significant	2	22.2			2	12.5
	crucial	1	11.1			1	6.3
	Group Total	9	100.0	7	100.0	16	100.0
Impact on scrutiny by universities	insignificant	5	55.6	6	85.7	11	68.8
	slightly significant			1	14.3	1	6.3
	moderately significant	3	33.3			3	18.8
	very significant	1	11.1			1	6.3
	Group Total	9	100.0	7	100	16	100

C.2 GRAPHICS

C.2.1 Tangibles

Figure 14. Existence of automated equipment.

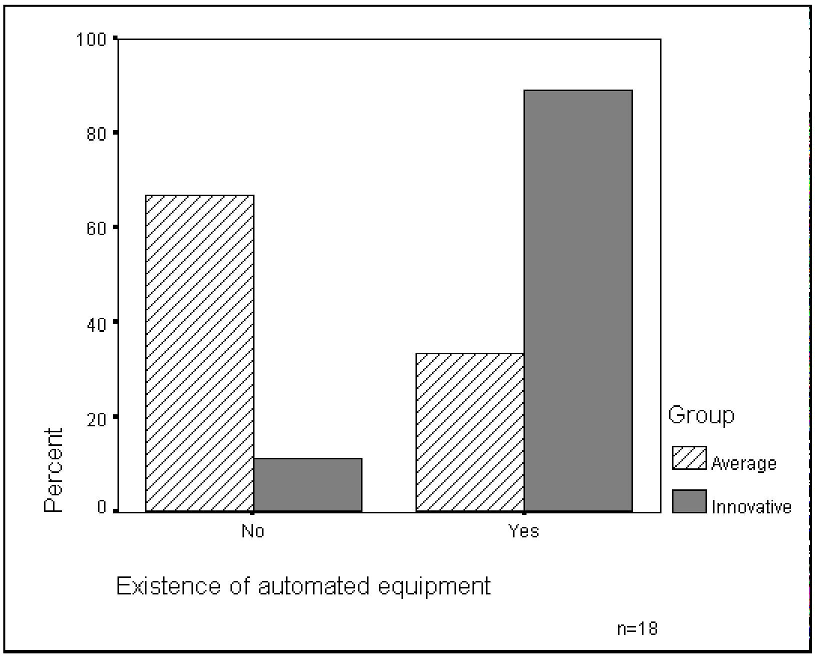


Figure 15. Predominance of old machines.

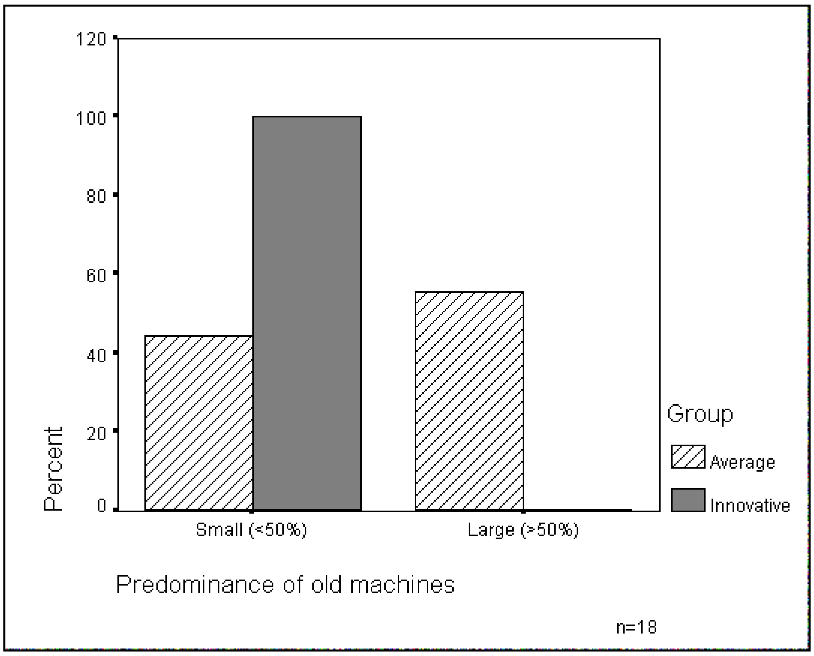
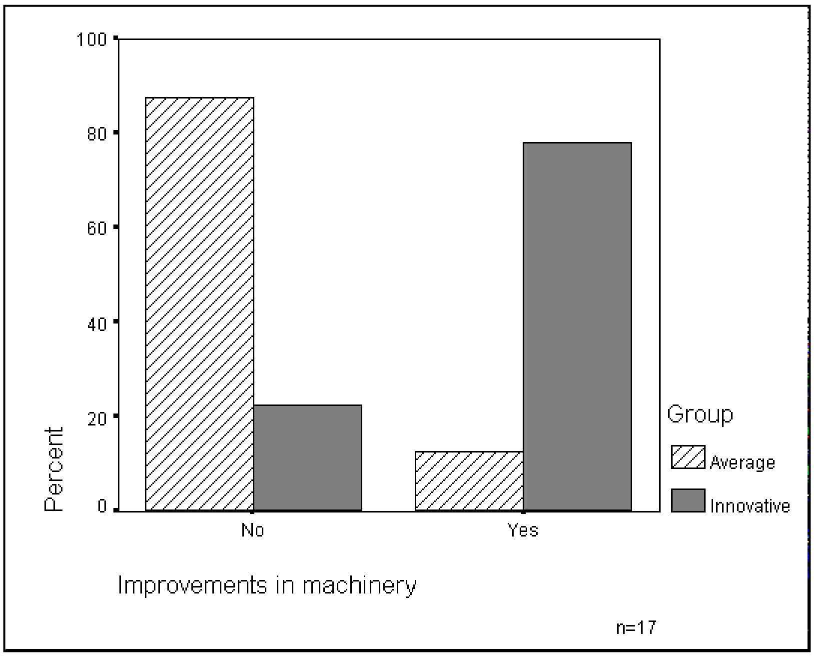


Figure 16. Improvements in production machinery.



C.2.2 Intangibles

Figure 17. Use of CAD.

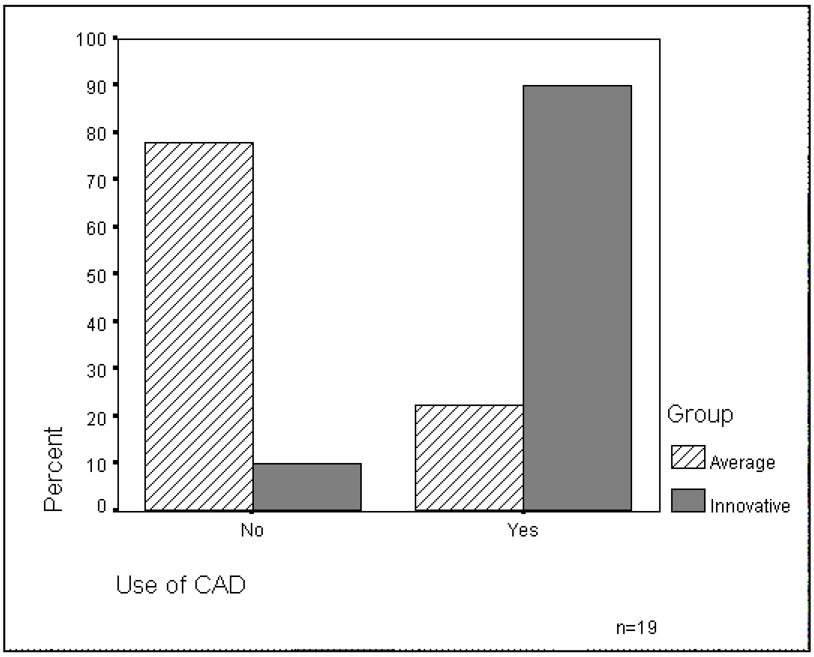


Figure 18. Use of CAM.

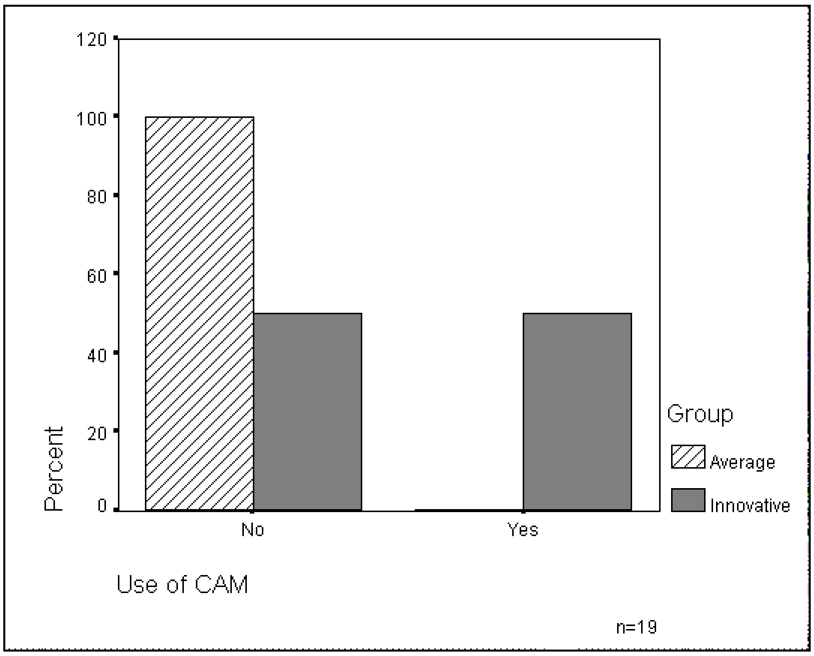


Figure 19. Internal quality control laboratory.

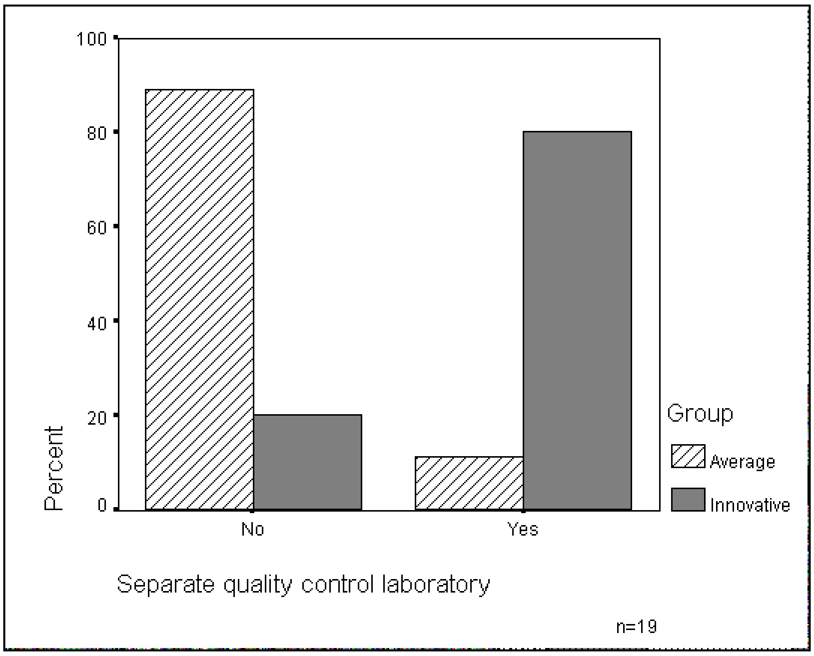


Figure 20. Existence of graduate personnel.

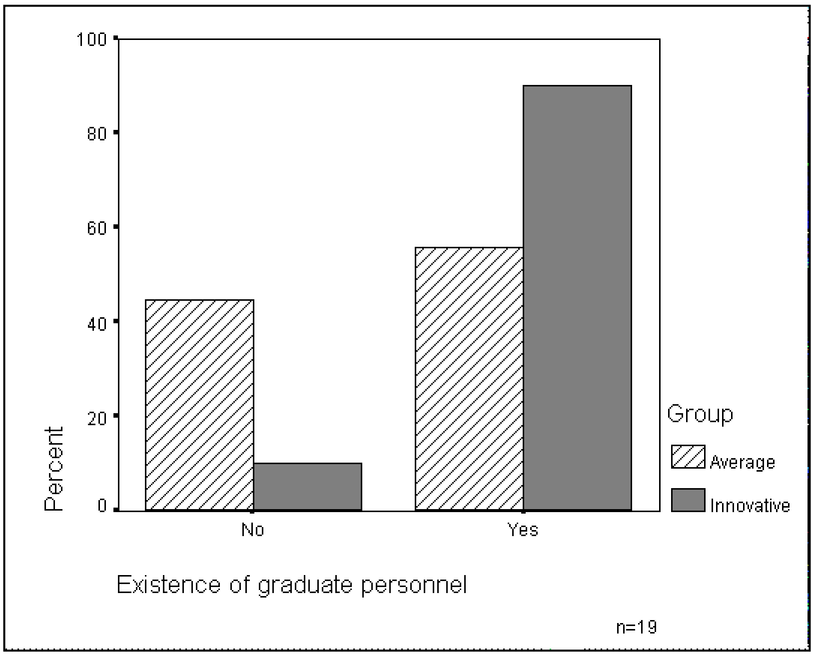


Figure 21. Type of training.

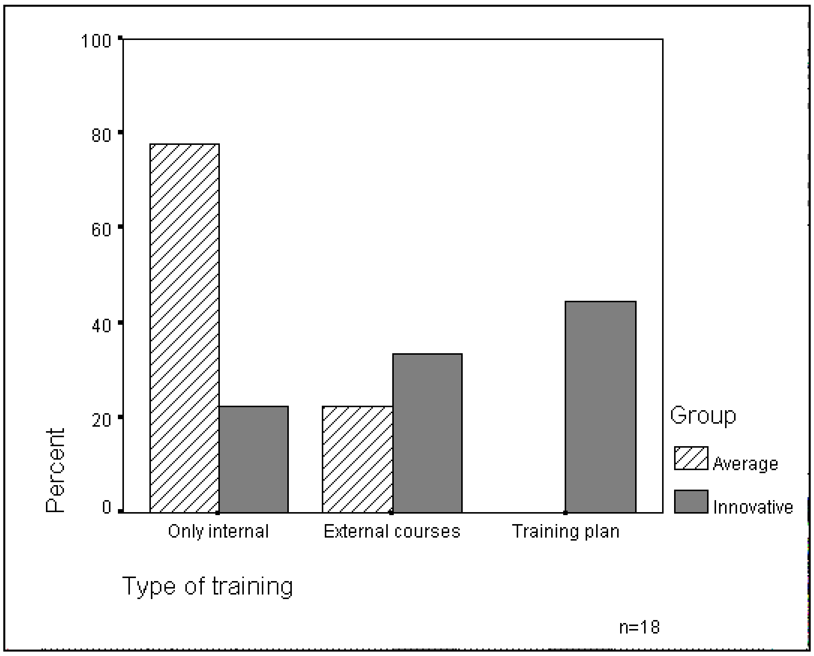
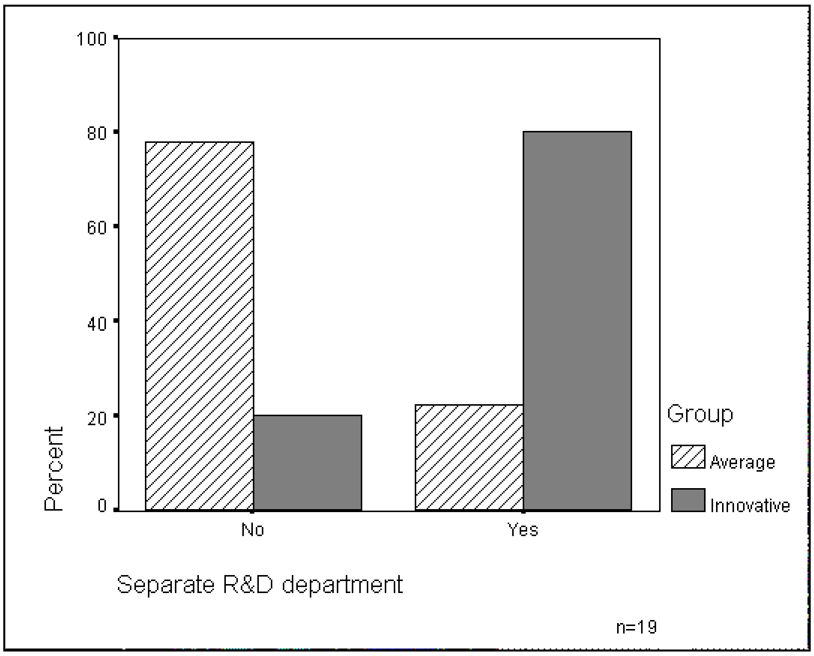


Figure 22. Separate R&D department.



C.2.3 Management

Figure 23. Main source of funds for investment.

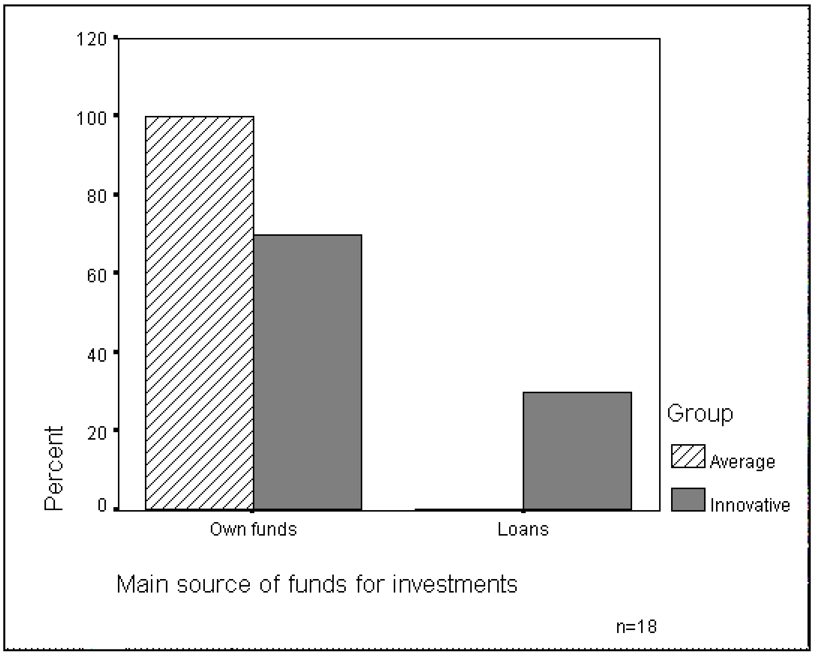


Figure 24. Receiver of subsidies.

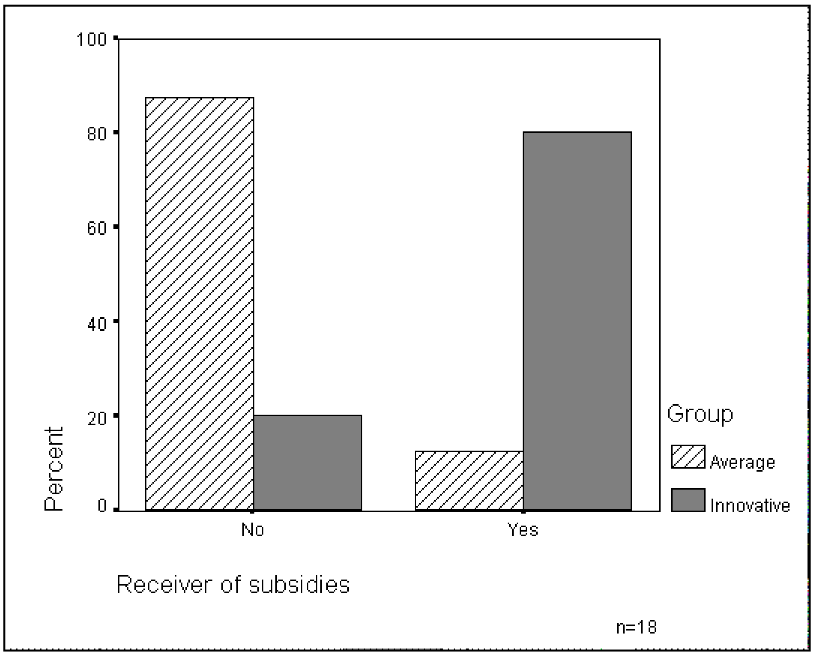


Figure 25. Type of strategy.

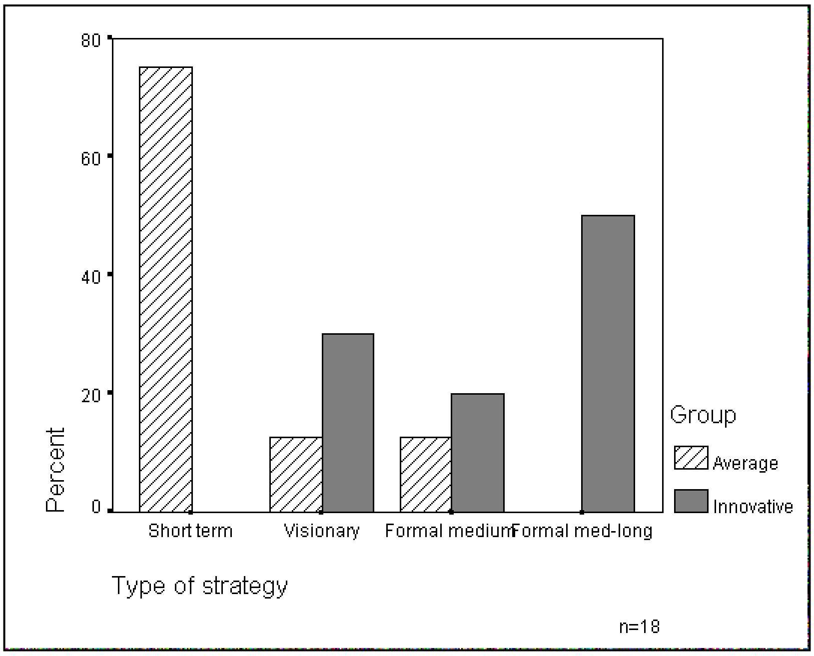
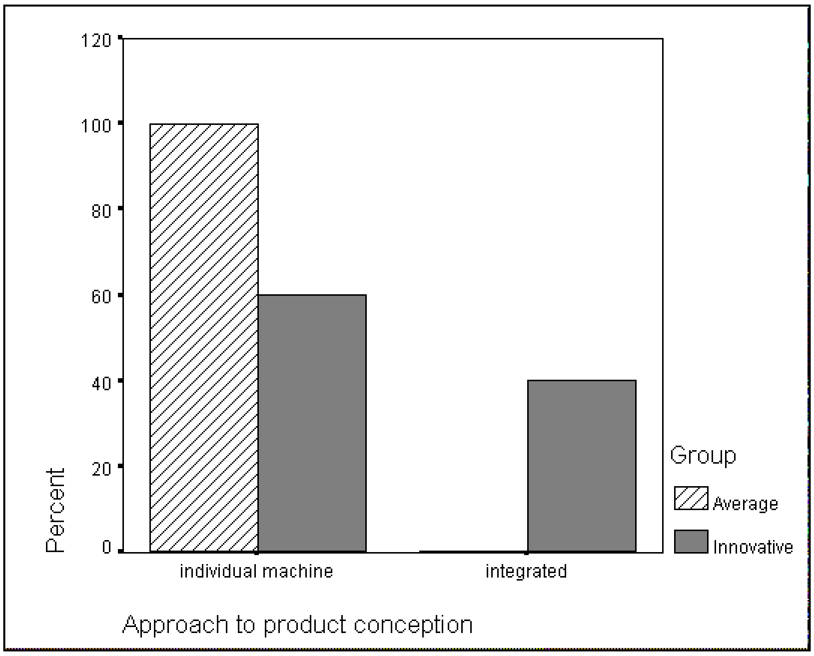


Figure 26. Approach to product conception.



C.2.4 External stimuli

Figure 27. Existence of exports.

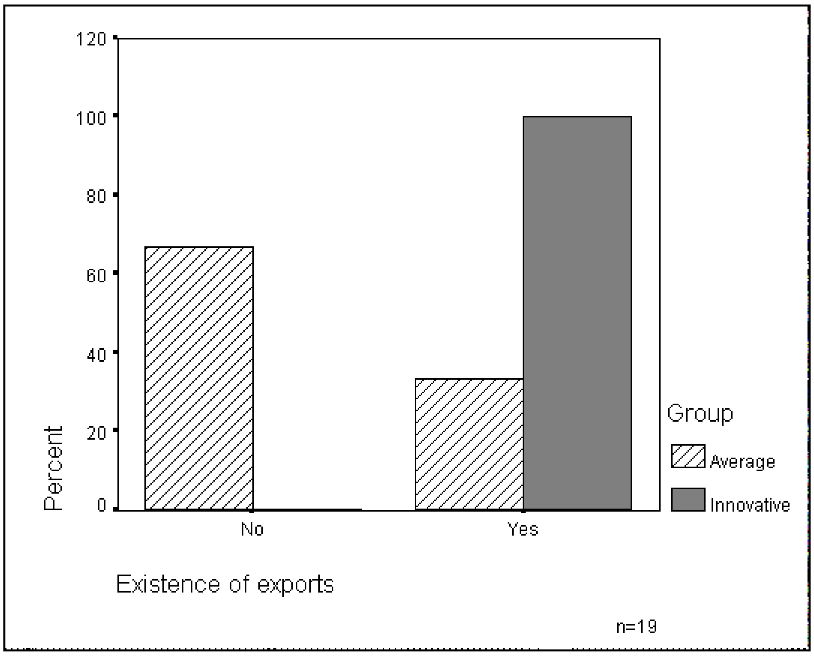


Figure 28. Importance of external competition.

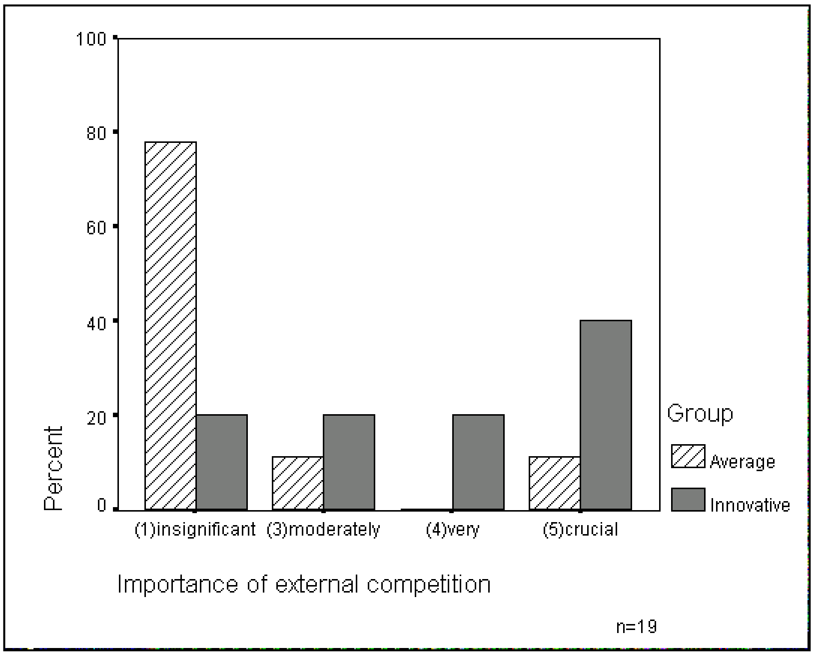


Figure 29. Type of domestic customer.

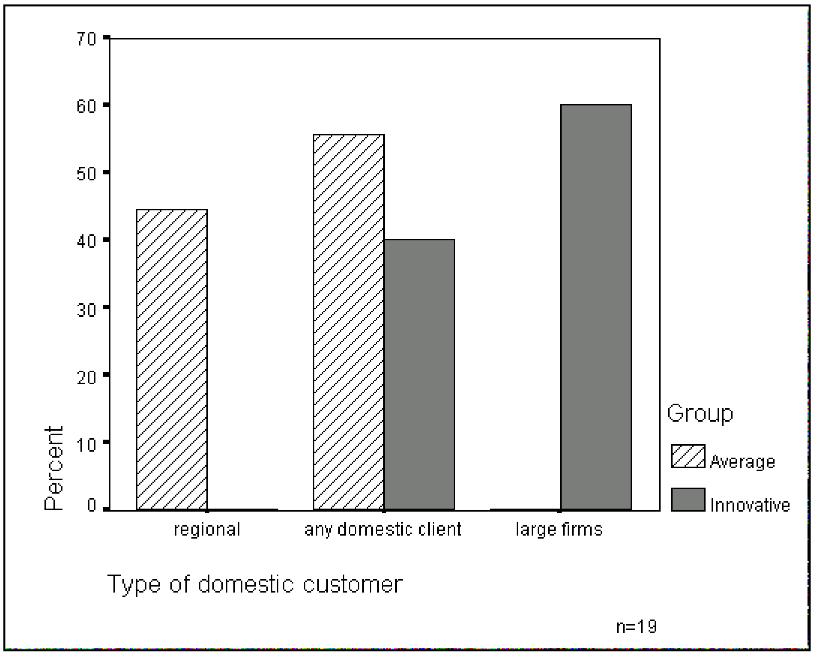
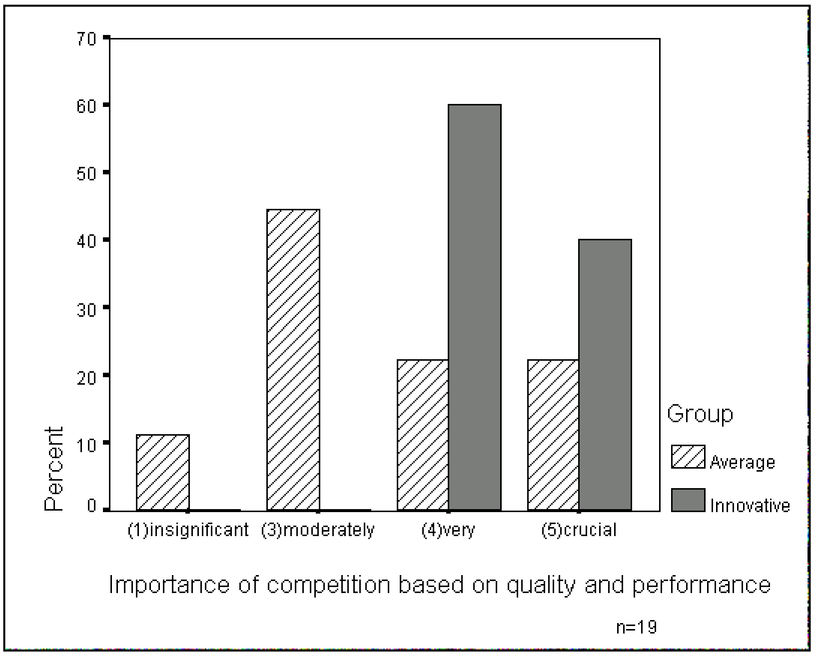


Figure 30. Competition based on quality and performance.



C.2.5 External sources of knowledge.

Figure 31. Impact of fairs on future innovations.

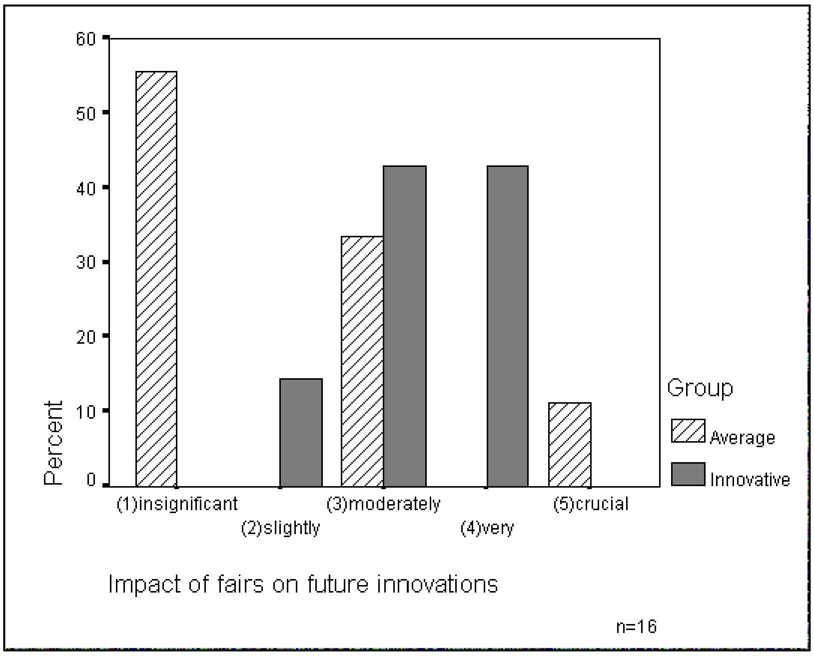


Figure 32. Impact of suppliers on scrutiny activities.

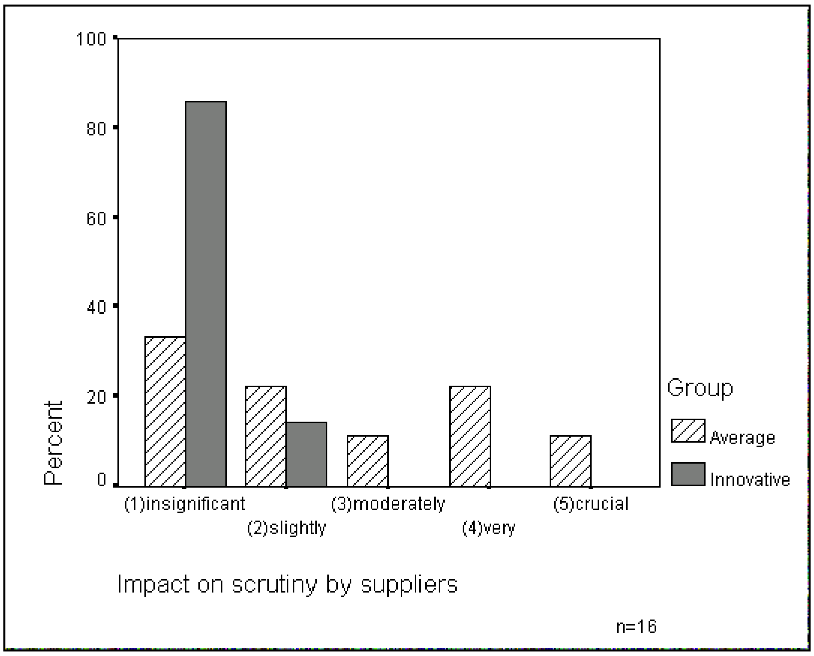
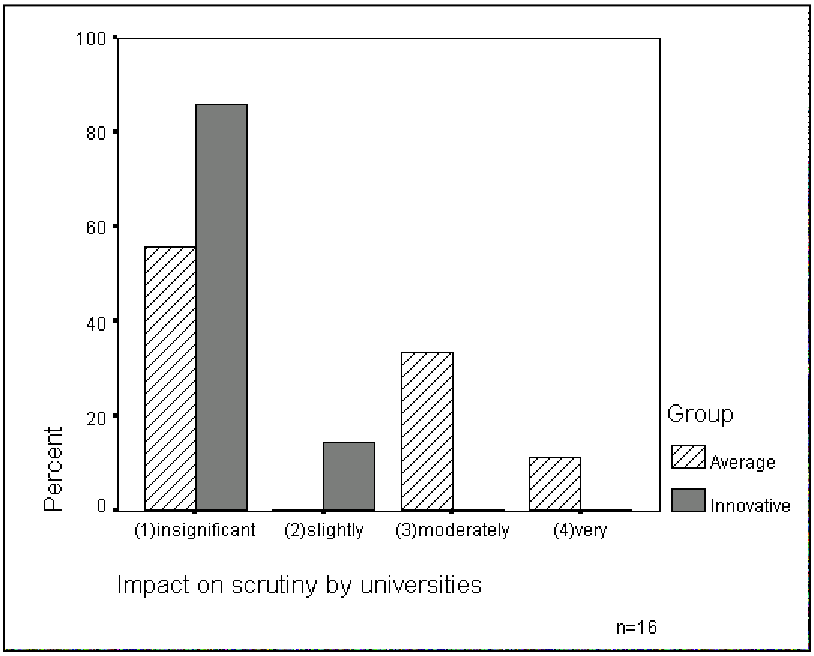


Figure 33. Impact of universities on scrutiny activities.



ANNEX D. LONG-TERM SERIES OF GDP, GDP PER CAPITA AND ANNUAL GROWTH RATES

	GDP (current prices) million escudos	GDP (1990p) Million escudos	GDP per capita (1990p) escudos	Average annual growth rates GDP	GDP per capita
1833	220	281576	78706		
1840	206	218476	58351	-3,6%	-4,2%
1850	224	249008	64457	1,3%	1,0%
1860	282	242224	59708	-0,3%	-0,8%
1870	392	341284	78027	3,5%	2,7%
1880	502	410491	87526	1,9%	1,2%
1890	679	523800	102453	2,5%	1,6%
1900	829	604541	111274	1,4%	0,8%
1910	947	683247	115345	1,2%	0,4%
1920	2629	424739	69885	-4,6%	-4,9%
1925	11368	595721	92954	7,0%	5,9%
1930	16304	873904	128236	8,0%	6,6%
1940	20220	1186013	152662	3,1%	1,8%
1945	30230	1127662	139092	-1,0%	-1,8%
1950	42255	1367172	160804	3,9%	2,9%
1960	74860	2144051	240867	4,6%	4,1%
1970	185668	4019418	464771	6,5%	6,8%
1973	294062	5183719	599758	8,8%	8,9%
1980	1306548	6555641	695704	3,4%	2,1%
1985	3661467	6830432	707964	0,8%	0,4%
1990	8560600	8560600	872819	4,6%	4,3%
1992	11343000	8880172	950263	1,8%	4,3%

Source: Neves (1994).

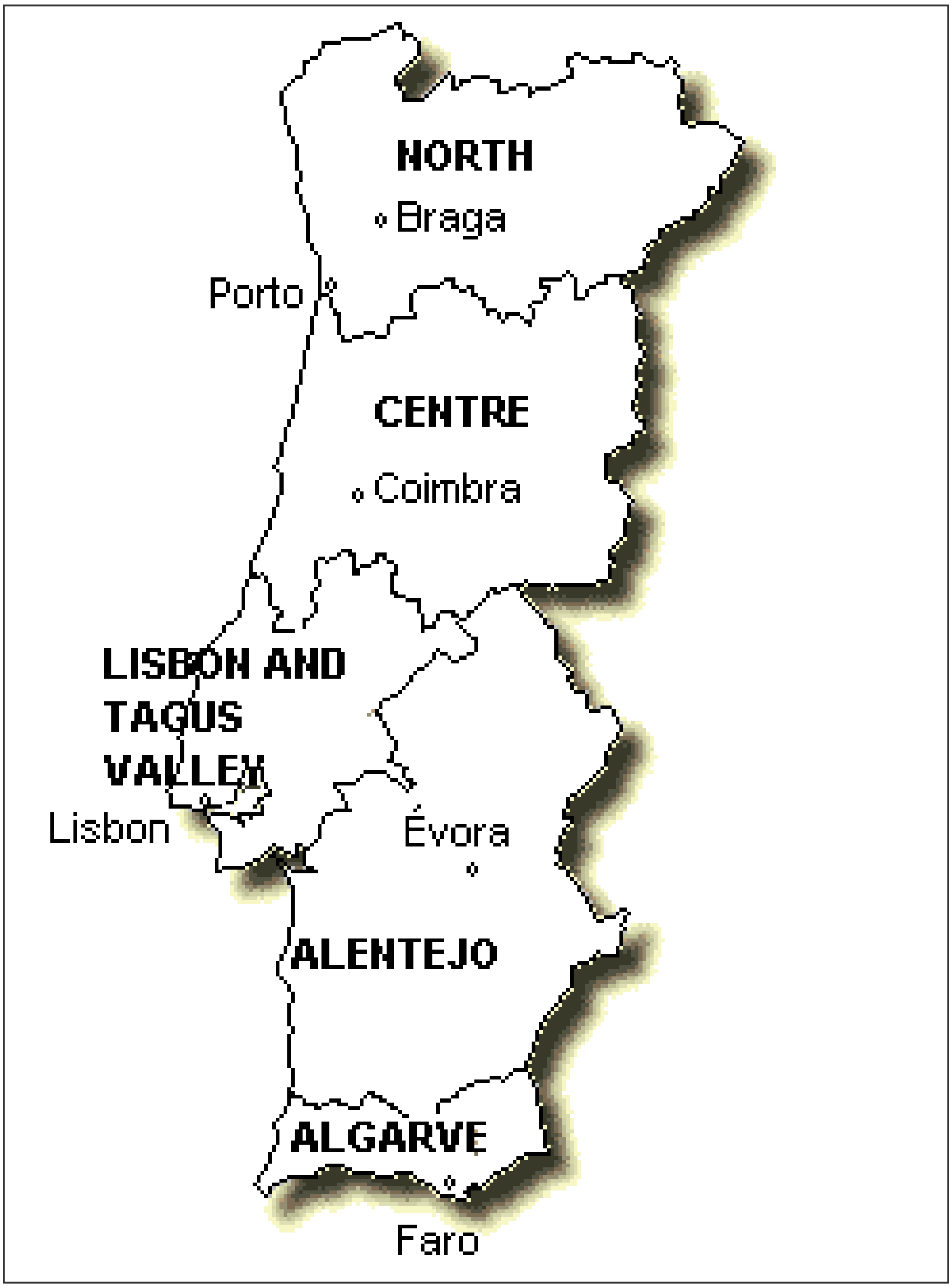
Note: The percentage refers to the period starting in the year located in the row immediately above and ending in the year located on the row.

ANNEX E. GROSS EXPENDITURE IN R&D: PERFORMANCE AND FUNDING, 1980-1995

(Current prices)			1980		1986		1990		1995	
			Esc. Million	%	Esc. Million	%	Esc. Million	%	Esc. Million	%
Government										
	Performance		1.947,4		7.150,6		13.240,2		24.572,3	
	Funding	Gov.	1.754,3	90,1%	6.199,7	86,7%	10.766,6	81,3%	18.629,1	75,8%
		HE	0,0	0,0%	0,0	0,0%	0,0	0,0%	0,0	0,0%
		PNP	0,2	0,0%	16,8	0,2%	33,8	0,3%	100,1	0,4%
		Firms	0,0	0,0%	292,8	4,1%	181,6	1,4%	62,1	0,3%
		Own	171,6	8,8%	441,8	6,2%	1.895,2	14,3%	3.711,6	15,1%
		Foreign	21,3	1,1%	199,5	2,8%	363,0	2,7%	2.069,4	8,4%
H. Education										
	Performance		819,7		5988,9		18.748,0		30.956,4	
	Funding	Gov.	785,1	95,8%	5745,6	95,9%	17.738,6	94,6%	27.135,1	87,7%
		HE	12,7	1,5%	74,8	1,2%	321,8	1,7%	884,8	2,9%
		PNP	14,9	1,8%	75,6	1,3%	153,4	0,8%	615,9	2,0%
		Firms	1,1	0,1%	51,6	0,9%	131,5	0,7%	234,4	0,8%
		Foreign	5,9	0,7%	41,3	0,7%	402,7	2,1%	2.086,2	6,7%

			1980		1986		1990		1995	
			Esc. Million	%	Esc. Million	%	Esc. Million	%	Esc. Million	%
PNP										
	Performance		171,8		1512,4		6.458,4		18.122,7	
	Funding	Gov.	1,1	0,6%	43,6	2,9%	863,4	13,4%	9.442,5	52,1%
		HE	0	0,0%	0	0,0%	0,0	0,0%	0,0	0,0%
		PNP	166,5	96,9%	900,9	59,6%	2.459,2	38,1%	1.687,9	9,3%
		Firms	4,2	2,4%	38,3	2,5%	1.689,2	26,2%	2.519,2	13,9%
		Foreign	0	0,0%	261,4	17,3%	1.065,9	16,5%	4.174,3	23,0%
		Other PNP	0	0,0%	268,2	17,7%	380,7	5,9%	298,8	1,6%
Firms										
	Performance		1179,6		5215,7		13.585,6		18.227,4	
	Funding	Gov.	39,4	3,3%	189,8	3,6%	882,1	6,5%	942,7	5,2%
		HE	0	0,0%	0	0,0%	6,0	0,0%	0,0	0,0%
		PNP	0	0,0%	0,4	0,0%	50,8	0,4%	48,7	0,3%
		Firms	1063,8	90,2%	4485,7	86,0%	11.910,7	87,7%	14.532,1	79,7%
		Foreign	50,9	4,3%	79,4	1,5%	581,9	4,3%	2.644,4	14,5%
		Other firms	25,5	2,2%	460,4	8,8%	154,1	1,1%	59,5	0,3%
Total			4.118,5		19.867,6		52.032,2		91.878,8	
Total foreign			78,1		581,6		2.413,5		10.974,3	
% foreign			1,9%		2,9%		4,6%		11,9%	

ANNEX F. PORTUGAL MAP.



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